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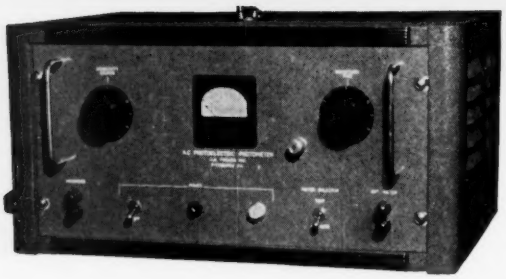

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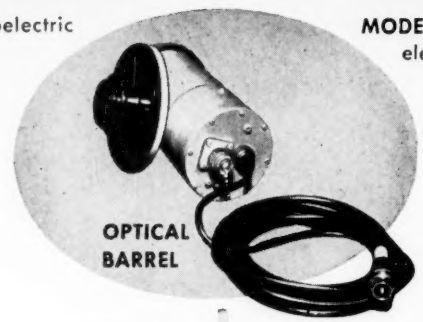

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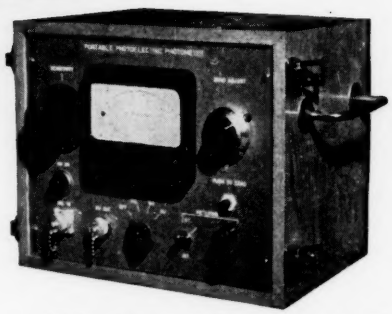

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For complete information write for Bulletin No. 155.

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Sky and TELESCOPE

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The principal articles are indexed in THE READERS' GUIDE TO PERIODICAL LITERATURE.

Solar Activity in February

AS THE SUN nears the peak of its activity that is predicted for early next year, spectacular solar disturbances like those of February are not unexpected. The following account is based on information from Dr. Walter O. Roberts, director of the High Altitude Observatory, Boulder, Colo.

Warning of unusual developments came on February 9th, when routine morning observations with the High Altitude Observatory's coronagraph at Climax, Colo., showed the rarely seen yellow spectrum line of the corona in a region at the northeastern edge of the sun. The occurrence of the yellow line indicates exceptionally high coronal temperatures.

The next day a violent eruptive prominence, rising faster than any previously recorded, was photographed at the Upper Air Research Observatory on Sacramento Peak in New Mexico. Also on February 10th, and again in the same region of the sun, astronomers at the McMath-Hulbert Observatory in Michigan observed an intense solar flare, which broke out at 21:10 UT. Simultaneously, there was an abrupt fadeout of short-wave radio transmission over the Western Hemisphere and the Pacific Ocean, lasting half an hour. At about the same time, the Colorado radio noise observatory of the National Bureau of Standards began recording large increases in radio emission from the sun.

During the next few days, solar rotation carried the disturbed region from the edge to the center of the sun's disk, and a great band of sunspots came into view. There were more than 50 individual spots, many larger than the earth, forming three distinct groups, which were strung out nearly one fifth of the way around the sun. A Philippine amateur, Hans Arber, took the picture of this area reproduced on page 329. This disturbed region passed the sun's central meridian on February 18th and 19th; contrary to expectations, there do not seem to have been either conspicuous auroras (at least in temperate latitudes) or marked geomagnetic storms.

However, in the same solar region, another very intense solar flare was recorded on February 23rd, at 3:30 UT, by Eastern Hemisphere observers. As this was during the night for American stations, their first indication of the event was a very marked increase in cosmic ray intensity, reaching a world-wide maximum greater than previously recorded. On the night of February 24-25, radio and geomagnetic disturbances occurred. The practically full moon hindered middle-latitude observations of the northern lights, but a red aurora was witnessed at College, Alaska, as described on page 329.

METEORITES — and Their Effects

OTTO STRUVE

Leuschner Observatory
University of California

The only specimens of extraterrestrial matter that can be studied in the laboratory are meteorites, such as this 355-pound mass of iron that was found at Knowles, in Beaver County, Okla., in 1903. It measures 24.5 inches long, 15 inches wide, and 8 inches high. Note the dark crust and rounded indentations, typical features which aid in the identification of meteorites. The Knowles iron is part of the meteorite collection of the American Museum-Hayden Planetarium in New York City.

THE ANCIENT GREEKS knew that from time to time fiery stones fell out of the sky, and there are mentions of such phenomena in old Chinese and Arabian chronicles. But during the Middle Ages these records were ignored or disbelieved. As late as 1772, Lavoisier in France attributed to the imagination of the people the stories about stones that had been seen falling upon the earth with a noise like thunder. At about the same time, the director of the museum of natural history in Vienna, A. A. Stütz, also denied the possibility of stones dropping from the heavens.

The first modern study of meteorites was made in 1794 by E. F. F. Chladni, a physicist at Wittenberg in Germany, and later a member of the Russian academy of sciences in St. Petersburg. Chladni's book was published in Riga, under the title, *On the Origin of the Iron Mass Found by Pallas, and Other Similar Objects*. This dealt with a large lump of iron, previously described by the Russian academician P. S. Pallas, which was to lead the scientific world to recognize the reality of objects falling from the sky.

This iron mass was found in 1749 by a peasant, Jacob Medvedev, in Siberia, on a hilltop about 15 miles from the river Yenisei. In 1750, a mining engineer named Mettich inspected the mass, describing it as weighing about 672 kilograms and having on its surface many small yellow stones the size of nuts. Local residents told that this lump of iron had fallen from the sky, but no attempt was made to verify these statements or to establish the time of the fall. Apparently, Mettich did not seriously consider the possibility of a cosmic origin of the body. However, in the belief that the mass might contain some precious metals in addition to iron, Medvedev transported it to his home, about 20 miles away. There it remained until it was examined in 1771 by Pallas.

The latter made a thorough study of the body, but reached the conclusion that it was of terrestrial origin and represented an unusual form of pure natural iron—the existence of which had not previously been recognized by mineralogists. Eventually, the main mass was brought to St. Petersburg, where it now rests in the mineralogical museum of the academy of sciences under the name of "Pallas' Iron."

The importance of this meteorite to the history of astronomy has often been overlooked, but it is clearly brought out by K. P. Massalskaya in her article, "Pallas' Iron: The Origin of Scientific Meteoritics," which appeared in the September, 1955, issue of the Russian journal *Priroda*.

A number of pieces were cut off from the main mass by Pallas and sent to scientists in other countries. One of these

The German geographer and naturalist, Peter Simon Pallas (1741-1811), was an unwitting father of the science of meteoritics. From 1768 to 1774 he made extensive explorations in Siberia, during which he inspected "Pallas' Iron," shown at the right. But Pallas concluded that it was of terrestrial origin, and Chladni was the first to recognize it as a true meteorite.

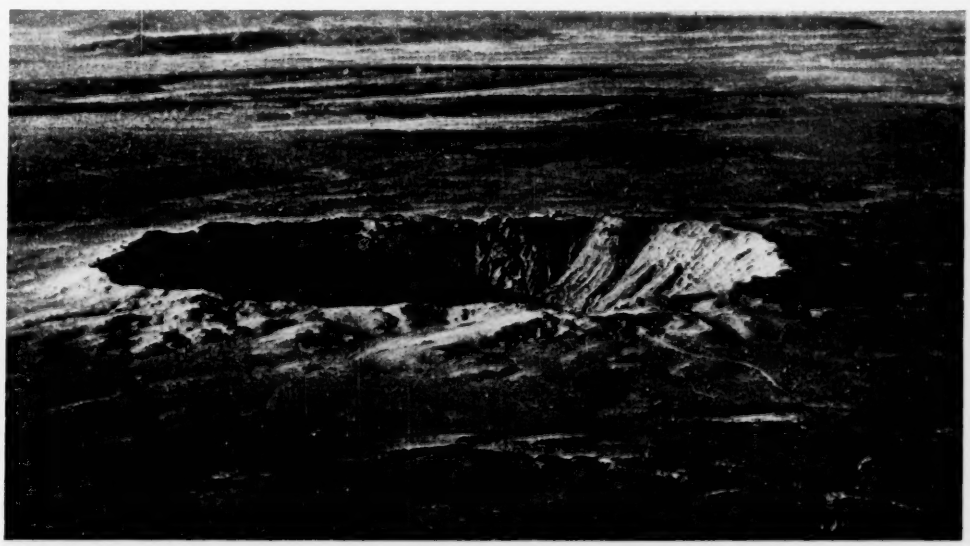
fragments reached Chladni, who had already studied fireballs and their orbits, and had concluded that these bodies could actually descend to the surface of the earth. He immediately recognized that Pallas' iron was just the kind of body that would, in passing through the earth's atmosphere, produce the phenomenon of a fireball.

Chladni realized that his hypothesis would arouse spirited debate. He remarked that many scientists cling to old, conventional opinions, rejecting new and unexpected advances. "Many of them would like to think of our little earth, so insignificant among other celestial bodies—and perhaps of their own personalities—as the most important things in the entire universe." And Chladni's announcement was, in fact, received with more skepticism than acclaim, as told in this magazine for June, 1953, by Helmut Heckscher in his article, "Stones from the Sky?" Some called it pure nonsense, while others suggested that Chladni had attempted a scientific hoax, in order later to ridicule the scientists. He was even accused of having tried to undermine the moral foundations of society! But Laplace and Olbers, and slightly later Cuvier and Biot, fully confirmed Chladni's conclusions.

These scientists of 150 years ago did not know that some meteorites strike the surface of the earth with such high energies that they produce craters in the ground. There is no lack of evidence to prove that the great Barringer crater in Arizona was caused by the fall of a giant meteorite or meteorites; this tremendous crater is about four-fifths of a mile in diameter and has interior walls 600 feet high. To understand how it was formed, and the crater-producing effects of large and small meteorites, consider the elementary problem of the energy possessed by a moving body.

For example, suppose a mass of one gram (0.035 ounce) is moving with a velocity of one centimeter (0.4 inch) per second. Then we assign to the energy of motion of this body—its kinetic energy—a value of half an erg. If we increase the mass to two grams, but keep the same velocity, the energy of motion is twice as great, one erg. Thus, if a mass of two grams collides with and is stopped by a stationary screen it will produce twice as much damage as a mass of one gram.

However, if we hold the mass equal to one gram but double the velocity, the



This aerial photograph of the great Barringer meteorite crater in Arizona was taken by the late Clyde Fisher, first curator of New York's Hayden Planetarium. It shows that the interior of the crater is hundreds of feet below the level of the surrounding plain. At some points along the rim may be seen very small specks; these are cedar trees of great age. American Museum of Natural History photograph.

damage is not twice but four times as great. The energy of motion is two ergs. To generalize, we say that the kinetic energy of a moving body is one half the mass, expressed in grams, multiplied by the square of the velocity, expressed in centimeters per second, that is, $E = \frac{1}{2}mv^2$, a well-known formula.

One erg is a very small unit of energy; it corresponds to the impact of a slowly flying mosquito. But we can also measure the energy in terms of the heat which a body produces on impact. In this case, the unit is a calorie—the amount of heat needed to raise the temperature of one gram (a cubic centimeter) of water by one degree centigrade. A calorie equals about 40 million ergs; we call this number the mechanical equivalent of heat.

Thus we can express energies either in ergs or in calories. For example, if we wish to heat 1,000 grams of water to the boiling point from room temperature, say from 20° to 100° centigrade, we need 1,000 (100 — 20) or 80,000 calories. Since each calorie is the same as 4×10^7 ergs, we require a total of 32×10^{11} or more than three trillion ergs! Burning 10 grams of coal or exploding a similar amount of nitroglycerin would provide this amount of heat.

Because their orbits have a variety of shapes, meteors travel through interplanetary space with different velocities. Those with circular orbits, and at the same distance from the sun as we are, have the same orbital velocity of 30 kilometers per second as the earth. But if a meteor's orbit is very elongated and extends out well beyond our own, its speed when 93 million miles from the sun could be about 40 kilometers per second. If we encountered such a meteor head-on, its speed with respect to the earth would be 40 + 30 = 70 kilometers per second. But if it were overtaking the earth, its relative motion would be 40 — 30 = 10 kilometers per second. The earth's gravitational attraction on the meteor has only a relatively small effect, especially for head-on collisions.

We are interested in the velocity with which the meteor strikes the earth's surface, and must take into account the resistance that slows the meteor when it enters the earth's atmosphere. This effect is quite sensitive to the mass of the meteor. Small grains will be greatly decelerated; they may fall on the ground as gently as raindrops, with almost negligible energies.

For much larger bodies, weighing a kilogram or more, the deceleration from air resistance is very small. Considering all types of encounters with the earth, meteorites of sufficiently large size can strike the ground with speeds ranging from nearly zero to 70 kilometers per second.

When the Siberian meteorite of 1908 fell, the air blast leveled great forests, the fallen trees pointing outward from the place of impact.

The famous Tunguska meteorite fell in Siberia in 1908. It was not only seen as a superbly brilliant fireball in full daylight from hundreds of miles away, but its heat was felt from a distance of 50 miles. I. S. Astapovich calculated that it had a velocity at impact of 60 kilometers per second. Its mass is not known, but has been estimated at more than one million tons. Let us compute the energy released on the impact.

Since one ton is about 10^6 grams, we may assume that the mass of the Tunguska meteorite was some 10^{12} grams, striking the earth at 6×10^6 centimeters per second. To obtain the energy we must square the latter number, giving us 3.6×10^{13}, and multiply it by the mass, 10^{12}. One half of the product, or 1.8×10^{25}, is the energy in ergs (the equivalent of 5×10^{17} calories).

This energy is comparable to that of a moderately strong earthquake. The great San Francisco earthquake of 1906 released 10^{27} ergs. No wonder, then, that the Siberian forest was completely destroyed for many miles around the point of fall of the Tunguska meteorite, and that an atmospheric pressure wave was produced which traveled several times around the earth.

Nor is it surprising that not a single meteoritic fragment or particle has ever been found at or near the point of impact. We do not even know whether this Siberian meteorite was of the iron or stony variety. Presumably all of the meteoritic material vaporized, together with an appreciable amount of soil and rock. The amount of heat required to vaporize a mixture of water, rock, and meteorite material would be somewhere around 1,000 calories per gram. Even for a violent explosion, consuming energy in chemical decomposition, only 10,000 calories per gram would be needed. The Tunguska meteorite could therefore have exploded $5 \times 10^{17}/10^4 = 5 \times 10^{13}$ grams, or 50 times the mass of the original colliding body!

It is, of course, not reasonable to assume that all of the energy of impact is converted into an explosion. We know that large meteorites produce craters, like the one in Arizona. Much energy was used to dig out such a hole in the ground, and large amounts of rock and soil were raised into the air and deposited as debris on the wall of the crater and on the area nearby. Working against gravity, half of the estimated energy of the Tunguska meteorite impact could lift a million times its own mass, or 10^{18} grams of material, to an average height of 100 meters.

This result is too large, for energy is also expended in shattering the terrestrial rocks, in pushing them sideways, and in producing earthquake waves. Let us very cautiously suppose that only one per cent of the energy is spent in lifting the material; the latter would then have a mass of 2×10^{16} grams.

With an average density of three grams per cubic centimeter (about equal to that of surface rocks), the volume of the excavated material would be 7×10^{15} cubic centimeters. This would roughly correspond to a hole two miles in diameter and half a mile deep, of the same order of size as the crater in Arizona.

But the velocity of the meteorite that formed the Barringer crater may have been much smaller than 60 kilometers per second, and the kinetic energy varies as the square of the velocity. Hence, at only 30 kilometers per second, the energy would have been four times smaller. To offset this, the mass of the meteorite has to be assumed four times larger to dig the same sized crater. It is thus reasonable to suppose, as E. Opik, L. LaPaz, and

others have done, that the Barringer crater was produced by a body weighing several million tons.

What was its original size? If it was a mixed stony and nickel-iron body, its density would have been about five grams per cubic centimeter. Again assuming for the mass a lower limit of a million tons or 10^{12} grams, its volume would have been 0.2×10^{12} cubic centimeters. Very roughly, then, we can think of the meteorite as a spherical body having a diameter of 75 meters.

Could such an object have been seen when it was outside the atmosphere of the earth, shining only by reflected sunlight? Suppose that, at a certain moment, it was fully illuminated at the average distance of the moon, 384,000 kilometers. What would have been its apparent stellar magnitude if seen in a telescope? The reflectivity of the moon and a meteorite are probably about the same, but the ratio of the areas of the two bodies would have been about 2×10^9. The apparent visual magnitude of the full moon is −12.6, but it is reflecting 2×10^9 as much light as our supposed meteoroid. Hence the latter would be some $23\frac{1}{2}$ magnitudes fainter, and would appear to us as a star of about the 11th magnitude, easily visible in a moderate-sized telescope. As far as we know, no such object has actually been discovered. If it had, the discoverer would have called it an unusual minor planet.

At the average distance of the moon, an asteroid moving through space perpendicularly to our line of sight, at 30 kilometers per second relative to the earth, would appear to travel about 15 degrees across the sky in an hour. This would be three times as fast as the asteroid Hermes appeared to move at its close approach to the earth in October, 1937, when it came within 500,000 miles. Hermes is presumably about three quarters of a mile in diameter, much larger than our proposed meteroid; therefore, at its closest it was much brighter, about magnitude 6.6.

Hermes was discovered by the trail it left on a photograph, taken by Karl Reinmuth at the Königstuhl Observatory in Germany. On his two-hour exposure, this asteroid left a sharp trail 27 millimeters long, but had Hermes been of the 11th magnitude there would have been no trace. The fact that astronomers use photography for the discovery of minor planets does not help us to find an 11th-magnitude meteoroid at the distance of the moon. Visual observations, perhaps by amateurs, offer more promise of discovering such an object.

Nevertheless, the fact that no one has ever reported a body of this character shows that there are not many of them in the volume of space extending out to the moon's orbit. This sphere exceeds the earth's volume by a factor of 2×10^5. If a Tunguska-type meteorite strikes the earth once every 1,000 years, we should expect about 200 to come within the moon's distance each year. But we cannot observe the entire volume all the time, and the chances are small of spotting such a fast-moving body. Nevertheless, telescope users ought to be ready to make accurate observations if they should, by good fortune, notice a starlike object that moves perceptibly with respect to the stars from minute to minute.

This problem is related, of course, to that of visual search for the proposed artificial satellite, which is expected to be about the 6th magnitude at its brightest, moving a degree a second across the sky and visible only in twilight. But with the artificial satellite, the would-be observer will have fairly detailed information on when and where to look, and what he should expect to see. Since such data are lacking in the case of the meteoroid, any deliberate search would probably be a waste of time; if this kind of object is ever picked up, the discovery will almost certainly be accidental.

Note the sharply upturned rock strata in this view of the interior wall of Barringer crater, at a place midway between the rim and the floor. This upturn indicates the explosive origin of the crater, for in the surrounding region the strata lie horizontally. This portion of the crater is opposite to that seen in the distance in the front-cover photograph.

UPPER-ATMOSPHERE EXPERIMENT

Much solar energy is stored in the earth's upper atmosphere, where ultraviolet sunlight is absorbed by oxygen molecules, splitting them into atoms of oxygen. Laboratory experiments have shown that in the presence of nitric oxide (NO), atomic oxygen recombines to form molecular oxygen, releasing the energy. Traces of nitric oxide occur naturally in the atmosphere, but there is too little of this gas to effect much recombination. Dr. Murray Zelikoff, a geophysicist at the Air Force Cambridge Research Center, therefore proposed transporting nitric oxide aloft, in the hope of securing a large-scale release of stored-up solar energy.

This experiment was carried out on the night of March 13-14, when an Aerobee rocket was launched from Holloman Air Development Center in New Mexico. At an altitude of 60 miles, the rocket released nitric oxide gas under high pressure.

Watchers on the ground saw appear a starlike light, nearly twice the brightness of the planet Venus. During the 10 minutes that the light remained visible to the naked eye, it grew into a patch four times the apparent diameter of the moon—corresponding to an actual width of about three miles. Instrumental observations could be made of the glow for a much longer period. The light was seen by observers more than 60 miles from the launching site.

On March 12th, in the daytime, nitric oxide was released from a rocket for radio experiments. The action of sunlight upon the gas formed an artificial cloud of electrically charged particles. Radio signals from a ground transmitter were reflected from the cloud—in the same way that the ionosphere reflects radio waves—and the echoes were picked up by a ground receiver. Such man-made ionospheric clouds, arranged in a row, could be perhaps used to extend the range of short-wave radio communications.

The Holleford Crater in Ontario

DISCOVERY of the Ungava crater in the northern part of Quebec province in 1950 (*Sky and Telescope*, November, 1951, page 2), and its identification as a probable meteorite crater by V. B. Meen, stimulated Canadian interest in crater problems. It suggested the Canadian shield of Pre-Cambrian rocks as an area where other similar topographic features might be found.

In 1951 an interesting circular feature was observed on aerial photographs of Algonquin Park not far from the village of Brent, Ontario. Geophysical studies on the ground indicated that this was a depression of considerable depth filled with Paleozoic sediments. Unfortunately, its age and degree of obliteration made difficult the application of the usual criteria of meteorite crater identification, such as the study of metallic fragments and comparison with the contours of known formations like Barringer crater in Arizona.

However, geological investigations failed to reveal any evidence of volcanic action, and considerable quantities of rock breccia were found near the rim of the crater. Subsequent drilling operations confirmed the presence of deep-lying rock breccia such as could have been produced by meteorite impact or explosion. It thus seems reasonable to regard this feature as a possible ancient or fossil meteorite crater.

Although mining and lumbering operations had been carried on for many years in and around the Brent crater, its discovery was only made possible by the study of aerial photographs. This suggested the desirability of a systematic search of aerial pictures of the Canadian shield and adjacent areas as a possible means of finding other similar objects. Such a search was begun by the Dominion Observatory in June, 1955, and during the summer approximately 200,000 photographs were examined, mainly of the province of Ontario and the southern part of Quebec. Several circular objects were found that might conceivably have had a meteoritic origin, but the most promising was at Holleford, Ontario, at latitude 44° 47′ north, longitude 76° 38′ west.

The Holleford crater is a circular depression approximately 100 feet deep and 1¼ miles in diameter. The village of Holleford is located partly within its boundaries, and easy access is provided by several roads that cross the rim or descend near the floor of the crater, as shown by the accompanying photograph.

The southern and southwestern parts of the rim are reasonably intact and form an impressive cirque of nearly 180 degrees, whose shape appears not to have been altered greatly by erosion. Other parts of the rim have been deeply eroded, and successive strata of limestone have been exposed, which indicates the probability that the original crater was buried under sedimentary deposits.

Most of the interior of the crater consists of farm land underlaid by limestone gently dipping toward the center, but an irregular inner area (dark on the photograph) is a wooded bog. Older geological maps, as well as a recent investigation by M. J. Frarey of the Geological Survey of Canada, identify the sedimentary covering of the crater as of Ordovician age.

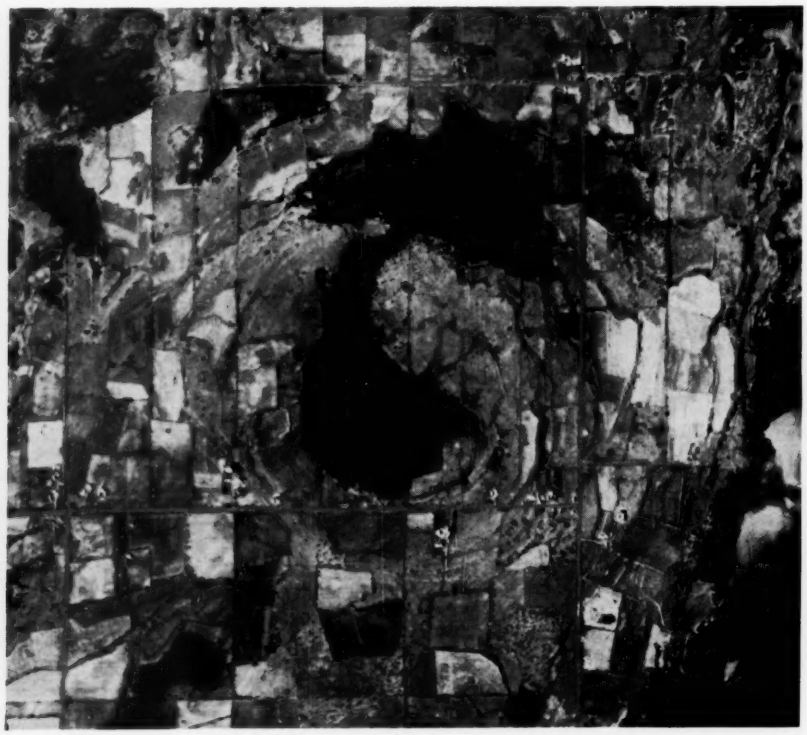
Examination with the stereoscope, which greatly exaggerates the relief, has shown that the inner slopes of the Holleford crater are much steeper than the outer, a characteristic of explosion craters. The actual slopes are relatively gentle; it seems clear that the original form of the crater has been greatly altered, certainly by the deposition of sediments and subsequent erosion and probably by erosion prior to deposition.

If subsequent investigation should reveal the crater to be of meteoritic origin, it would be one of the largest known. It is slightly larger than the recently discovered crater of Talemzane in southern Algeria, but still much smaller than the Ungava crater or the Brent crater in Canada.

Knowledge of the Holleford crater is now confined to what can be derived from the aerial pictures and a general examination on the ground. However, a gravity survey has been made by M. J. S. Innes and his colleagues of the Dominion Observatory gravity division, and it is hoped that eventually these observations will provide an estimate of the original depth of the crater.

Our program of examining aerial photographs is continuing, with the hope that additional craterlike features may be discovered.

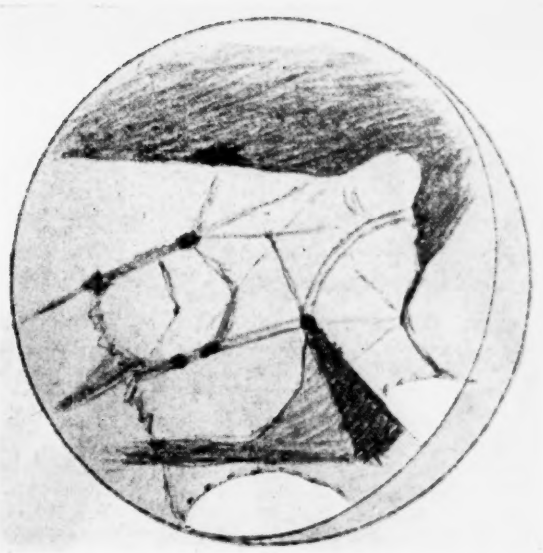
C. S. BEALS
G. M. FERGUSON
A. LANDAU
Dominion Observatory, Ottawa



This is an aerial view of the Holleford crater region, with the reproduction scale about one inch to 3/8 mile. The aircraft was flying 8,420 feet above sea level, and the exposure time was 1/200 second. North is toward the top. Photograph by Royal Canadian Air Force.

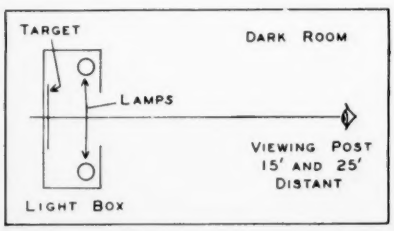
VISUAL PROBLEMS OF MARS

WILLIAM D. CARRAGAN



Percival Lowell drew this picture of Mars on June 19, 1905. It has many features typical of his work: straight, narrow canals, sometimes double, and often converging on an oasis. The pentagonal area left of center is Elysium.

MARS is the only planet in the solar system except Mercury whose solid surface can actually be observed in detail. In the telescope, the brick-red Martian disk appears overlaid with large green, brown, or blue diffuse markings which change slightly from year to year, and more markedly with the planet's seasonal cycle. Harder to see are the peculiar features called canals. To some observers the canals are straight lines hundreds of miles in length, intersecting to form a geometrical network, whose artificial appearance was cited by Lowell as evidence of intelligent life on Mars. Other observers, however, see the canals as diffuse bands, or as masses of minute irregular detail.



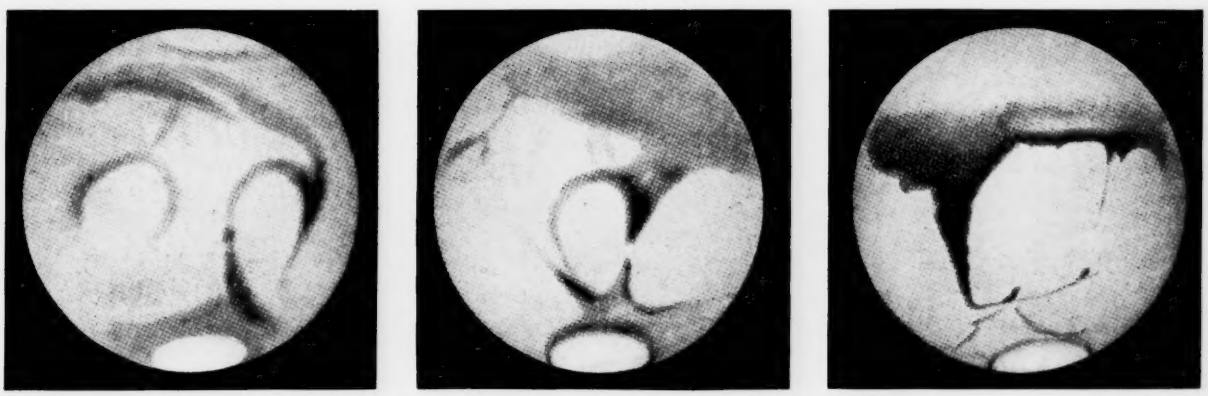
This arrangement was used by the author for illuminating paper targets in his laboratory study of the psychology of planetary observing.

Such striking differences in the results of trained observers suggest at once the importance of optical illusions in the interpretation of these delicate formations. Laboratory experiments are needed to tell us what underlying Martian surface pattern could lead to such discordances, when viewed by different eyes. Considerable work on this problem was done in the first years of this century by J. E. Evans and E. W. Maunder, S. Newcomb, P. Lowell, and W. H. Pickering. They investigated in addition the angular diameters of the smallest features visible to the eye, finding that a black dot could be seen against a bright background if its apparent angular diameter was at least 34 seconds of arc, and that a dark line could be so seen if its width was about one second.

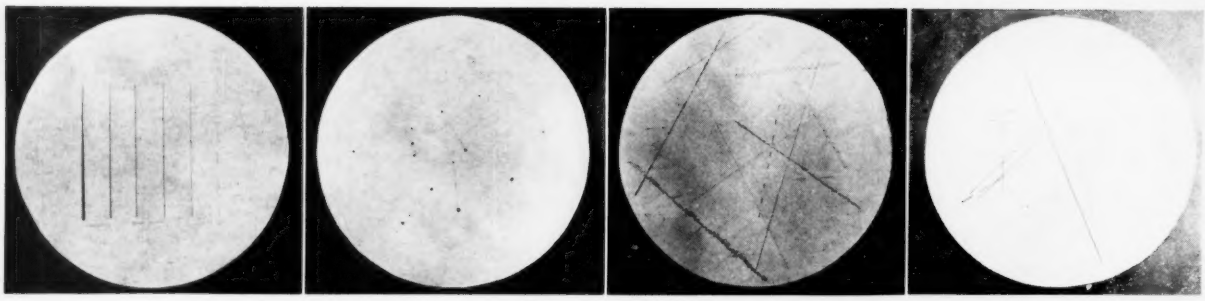
During 1953 and 1954 I made a series of experiments at Troy, N. Y., on the interpretation of Martian detail. In the program, seven observers made a total of 104 sketches of 11 red paper targets, containing patterns of dots, lines, and shaded areas.

To simulate actual observing conditions, the experiments were carried out in a darkened room, and the targets were indirectly illuminated at a brightness level corresponding to the actual planetary disk. The 8-inch targets were made of brick-red photographic masking paper, on which black markings were drawn in India ink with ruling pen and crow quill. Opaque show-card colors were used for colored lines, and shadings were added with lead and wax pencils.

Great pains were taken to avoid bias on the part of the observers, who were selected on the basis of conscientiousness and observing ability. They had, however, little or no prior knowledge of the telescopic appearance of Mars. They were not instructed to look for any special effects such as double canals. The Shinobu Ishihara color-blindness tests were used to check on the observers' color vision. The observers wore eye patches



Intercompare the styles of these three Mars drawings by experienced British amateurs and the Lowell portrayal above. At the left is a sketch by T. E. R. Phillips on February 6, 1916, of the same region as in the Lowell drawing. In the middle, by H. Thomson on March 3, 1916, Elysium is just visible at the left edge of the disk, and the large dark triangular patch, Syrtis Major, is nearly central. The third drawing, made by W. F. A. Ellison on January 22, 1916, also shows Syrtis Major. From the "Memoirs" of the British Astronomical Association.



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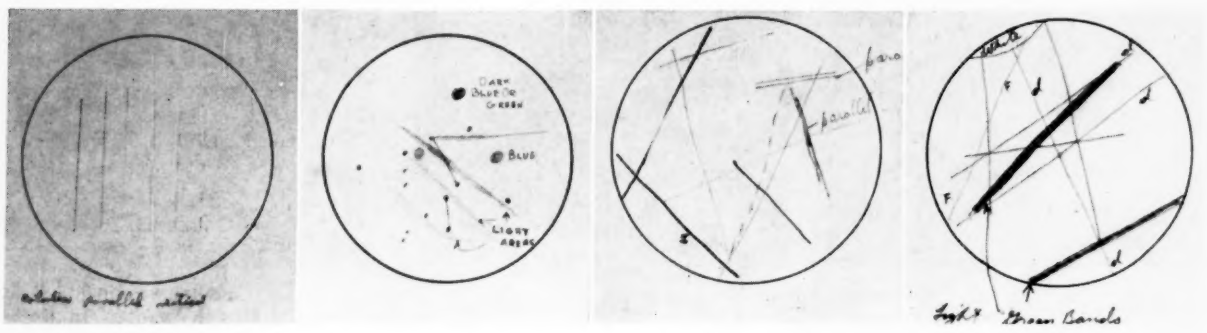

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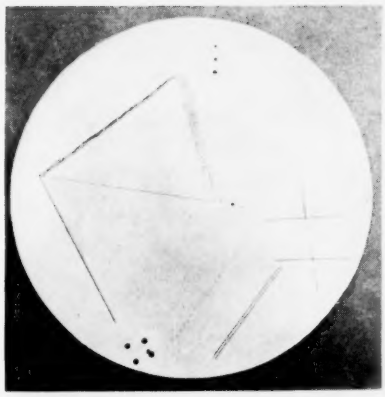

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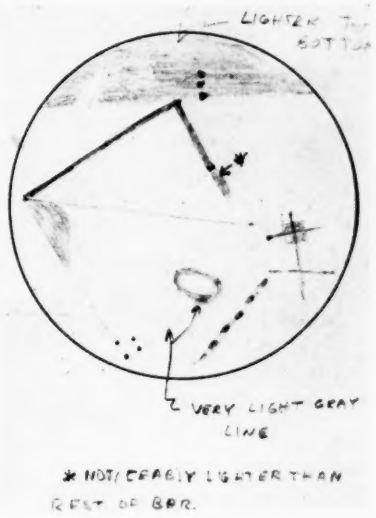

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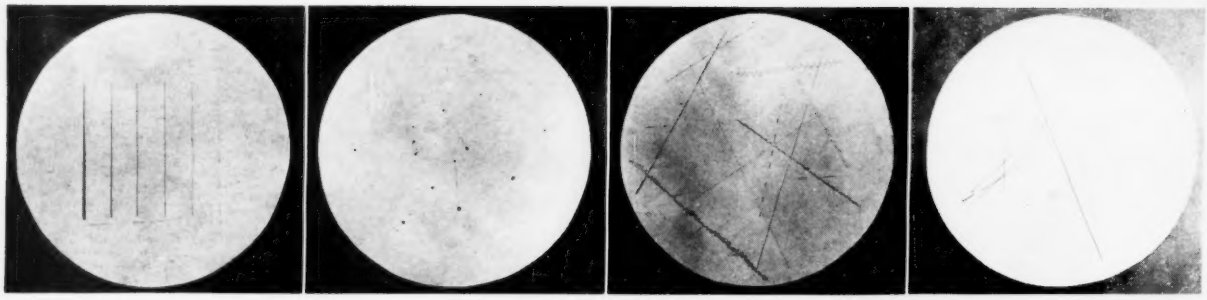

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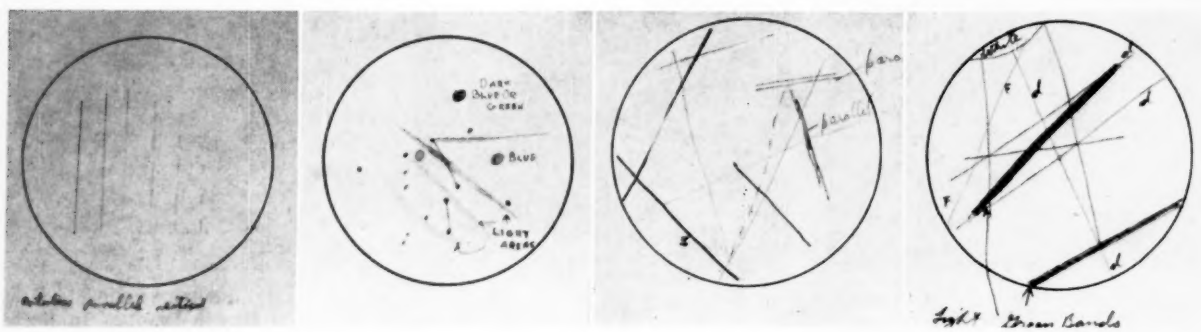

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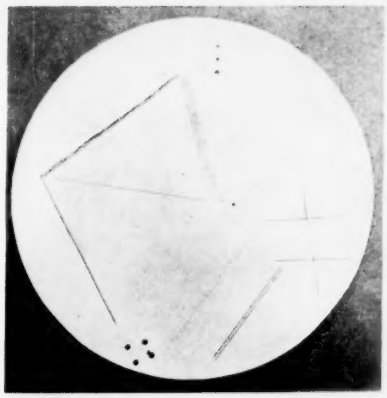

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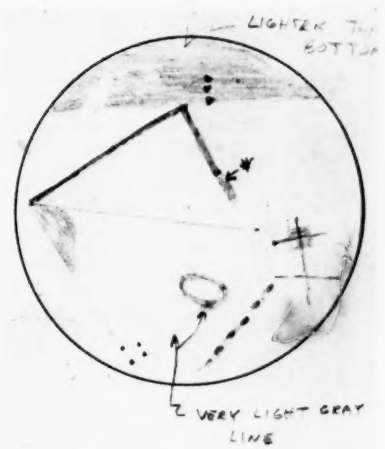

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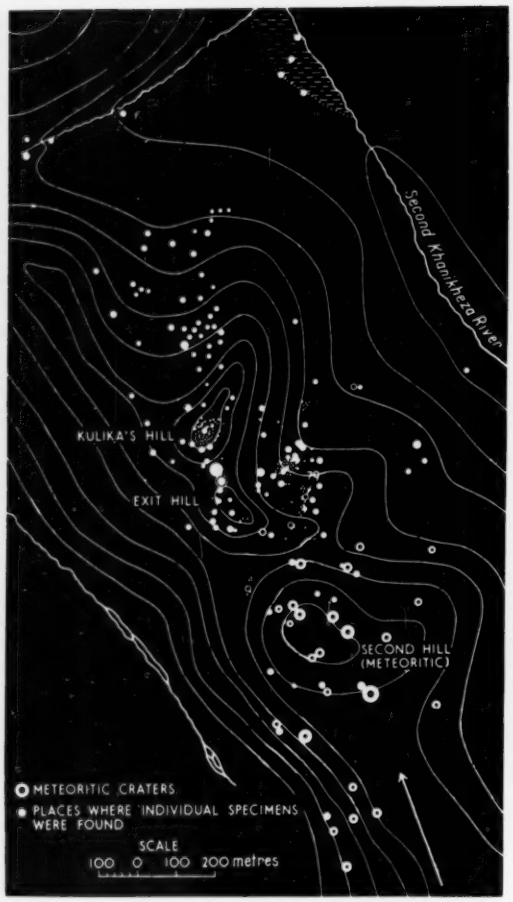
The Siberian Meteorite Fall of February, 1947

E. KRINOV

Meteorite Committee
USSR Academy of Sciences



The immediate area of the meteorite fall, with the direction north indicated by the arrow in the lower right. Individual specimens were found at considerable distances from the large craters, giving a good indication of the direction of flight, for they lagged behind the main meteorite masses.

A GREAT SHOWER of iron meteorites fell in eastern Siberia on February 12, 1947, at about 10:38 a.m. local time. It spread over an area of 1.6 square kilometers on the western spurs of the Sikhote Alin mountain range, several hundred miles north of Vladivostok.

This shower was accompanied by very striking phenomena. A scintillating ball of fire with a luminous tail and sparks sped for several seconds across the cloudless sky in broad daylight. The bolide was so bright that it blinded the eyes of people who watched it, and it cast moving shadows. In its wake there remained a wide gray band of dust, which was seen for several hours. Some minutes after the fireball disappeared powerful detonations were heard, resembling explosions or the firing of heavy guns.

The place where the shower fell was found by pilots who flew over the taiga forest. From a height of about 2,300 feet, among the trees they noticed craters standing out sharply against the snowy background, because of the yellow-brown color of the uncovered clay and rock.

Soon geologists from Khabarovsk and Vladivostok arrived by plane at the site. They made a preliminary survey of the area, finding craters of various sizes containing iron meteorite fragments.

An expedition of the meteorite committee of the USSR Academy of Sciences reached the area at the end of April, after the snow had melted. It consisted of scientists and technicians, and was headed by Prof. V. G. Fessenkov. This expedition started a comprehensive study of the circumstances of the fall of the meteorite, questioning more than 300 eyewitnesses in over 50 inhabited places, with the object of tracing the meteorite's path through the atmosphere and its orbit in interplanetary space.

Other expeditions of the meteorite committee were sent to the region from 1948 to 1950. Altogether, the four field parties that were there at different times worked for 19 months. Several more years

At the left, an individual specimen bears evidence of the pitting by the atmosphere through which it fell. At the right, a section of a specimen has been polished and etched to reveal its internal structure. Note the dark veins, which explain the ease with which the original body broke apart.

were required for analyzing the abundant data, and the project was completed only in 1955.

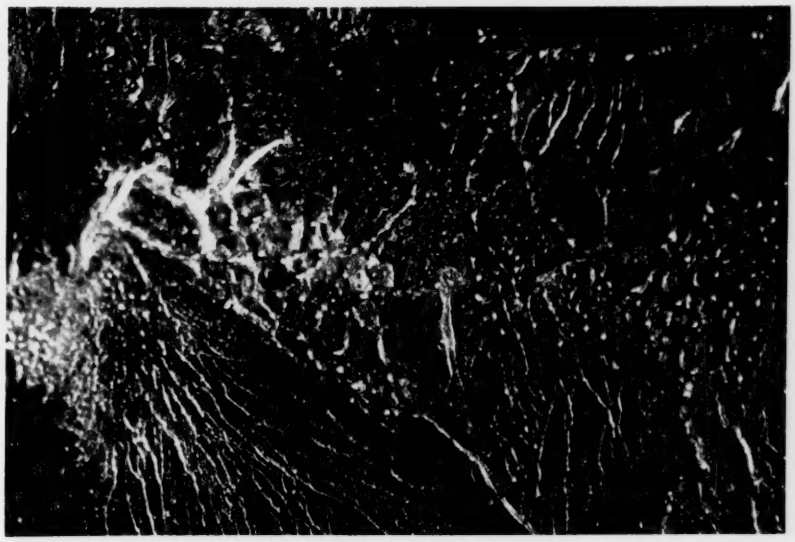
The Sikhote-Alin meteorite shower was a very rare and remarkable natural phenomenon, in many respects of outstanding scientific importance. The total mass of the fall is calculated at approximately 70 tons. It was the only known case in history when people actually witnessed the arrival of such a huge cosmic mass. The largest meteorites in the world—including the 60-ton iron mass at Hoba West, in Southwest Africa, the biggest single meteorite known—have all been found accidentally, and the dates of their falls are unknown.

A shower like the Sikhote-Alin occurs when an iron meteorite enters the atmosphere from interplanetary space and bursts into thousands of fragments. The observers' reports lead to the conclusion that this meteoroid was moving around the sun in an orbit resembling those of some asteroids, but crossing the orbit of our planet. On February 12, 1947, both the earth and the meteorite happened to be at the intersection point. As a result, the body encountered the atmosphere at a velocity of about 14½ kilometers per second.

The meteorite exploded in the atmosphere into fragments of the most diverse shapes and weights, from fractions of a gram to several tons. The biggest pieces, weighing hundreds and thousands of kilograms, broke up further on striking the rocky ground. Smaller fragments, so-called individual specimens, fell to earth intact. These differ from the other fragments in being covered by a fused crust of dark-gray color, and on their surfaces are peculiar round pittings caused during their descent through the atmosphere. On the other hand, the pieces formed by the breakup of the large masses on striking the ground have sharp-pointed and bent edges, sharp indentations, and the like.

The expeditions located 122 craters ranging in diameter from about 1½ to 90 feet. The depth of the biggest crater was 20 feet. They also found 78 holes less than 1½ feet across, and collected 175 small specimens on the surface of the ground. All the craters, holes, and places where the small specimens fell are located inside an elliptical area. The big craters lie mostly in the southern part of this area, and the small specimens in the northern part.

The black dot on this map marks the approximate location of the Sikhote-Alin meteorite fall.



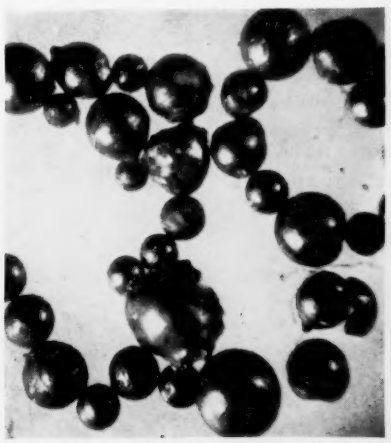
During the meteorite's rapid flight through the atmosphere, its surface was heated to incandescence and fused to form the tiny droplets and veins seen here. All of the photographs with this article are from the Meteorite Committee, USSR Academy of Sciences.

Of the 200 craters and holes, 181 were excavated. Several craters of different sizes were left untouched as natural monuments. The collected meteoritic material that was shipped to Moscow for study weighed approximately 23 tons. Fine meteoritic dust—particles formed when the big fragments broke up—was discovered with the help of a magnet, in the earth that filled the big and middle-sized craters and in the surrounding soil.

The intricate structure of the fused crust covering the individual specimens shows the action of the air on the meteoritic masses as they sped through it. Many specimens had on their surfaces congealed drops of the molten matter blown from their protruding parts. Vast numbers of these drops sprayed through the atmosphere and hardened into tiny balls, with diameters of tenths or hundredths of a millimeter, forming the dusky trail seen in the sky after the bolide disappeared. Gradually these particles settled on the earth's surface. The dust was found in soil samples from the area of the fall. This was the first time scientists had made so thorough a study of the tiny particles forming the dust train of a meteorite. The shapes and surfaces of individual specimens also helped us gain a better idea of how meteoritic bodies break up during flight.

Examination of the internal structure of parts of the Sikhote-Alin iron meteorite showed that they appeared to be pressed together from separate pieces, these ranging in size from less than a millimeter to several centimeters. Frequently there are thin layers of the mineral schreibersite (a compound of iron and phosphorus) between the separate pieces. This structure, and the existence of the layers, facilitated the breaking up of the meteorite in the air and permitted the bigger pieces to split into thousands of fragments on striking the ground.

Chemical analyses gave the following composition of the fragments: iron, 93.5 per cent; nickel, 5.27; cobalt, 0.47; phosphorus, 0.20; and sulphur, 0.06. Tiny quantities of other chemical elements were also found.



Microscopic droplets of meteorite material such as these formed the dusky train of the fireball and then gradually settled down to earth.

HERSCHEL'S "Lunar Volcanos"

One of the curiosities of lunar literature is the report read by William Herschel before the Royal Society on April 26, 1787, which is here reprinted from his COLLECTED WORKS (1912), at the suggestion of Frank H. Boothby, of Portland, Ore.

Sir William Herschel at the age of 46, after the painting by L. T. Abbot, made in 1784. By this time Herschel was already famous as the discoverer of the planet Uranus.

An Account of Three Volcanos in the Moon

"IT WILL BE necessary to say a few words by way of introduction to the account I have to give of some appearances upon the moon, which I perceived the 19th and 20th of this month [April, 1787]. The phenomena of nature, especially those that fall under the inspection of the astronomer, are to be viewed, not only with the usual attention to facts as they occur, but with the eye of reason and experience. In this we are however not allowed to depart from plain appearances; though their origin and signification should be indicated by the most characterising features. Thus, when we see, on the surface of the moon, a great number of elevations, from half a mile to a mile and an half in height, we are strictly entitled to call them mountains; but, when we attend to their particular shape, in which many of them resemble the craters of our volcanos, and thence argue, that they owe their origin to the same cause which has modelled many of these; we may be said to see by analogy, or with the eye of reason. Now, in this latter case, though it may be convenient, in speaking of phenomena, to use expressions that can only be justified by reasoning upon the facts themselves, it will certainly be the safest way not to neglect a full description of them, that it may appear to others how far we have been authorized to use the mental eye. This being premised, I may safely proceed to give my observations.

"*April 19, 1787,* $10^h\ 36^m$ sidereal time. I perceive three volcanos in different places of the dark part of the new moon. Two of them are either already nearly extinct, or otherwise in a state of going to break out; which perhaps may be decided next lunation. The third shews an actual eruption of fire, or luminous matter. I measured the distance of the crater from the northern limb of the moon, and found it $3'\ 57''.3$. Its light is much brighter than the nucleus of the comet which M. Méchain discovered at Paris the 10th of this month.

"*April 20, 1787,* $10^h\ 02^m$ sidereal time. The volcano burns with greater violence than last night. I believe its diameter cannot be less than $3''$, by comparing it with that of the Georgian planet [Uranus]; as Jupiter was near at hand, I turned the telescope to his third satellite, and estimated the diameter of the burning part of the volcano to be equal to at least twice that of the satellite. Hence we may compute that the shining or burning matter must be above three miles in diameter. It is of an irregular round figure, and very sharply defined on the edges. The other two volcanos are much farther towards the center of the moon, and resemble large, pretty faint nebulae, that are gradually much brighter in the middle; but no well defined luminous spot can be discerned in them. These three spots are plainly to be distinguished from the rest of the marks upon the moon; for the reflection of the sun's rays from the earth is, in its present situation, sufficiently bright, with a ten-feet [focal length] reflector, to shew the moon's spots, even the darkest of them: nor did I perceive any similar phenomena last lunation, though I then viewed the same places with the same instrument.

"The appearance of what I have called the actual fire or eruption of a volcano, exactly resembled a small piece of burning charcoal, when it is covered by a very thin coat of white ashes, which frequently adhere to it when it has been some time ignited; and it had a degree of brightness, about as strong as that with which such a coal would be seen to glow in faint daylight.

"All the adjacent parts of the volcanic mountain seemed to be faintly illuminated by the eruption, and were gradually more obscure as they lay at a greater distance from the crater.

"This eruption resembled much that which I saw on the 4th of May, in the year 1783; an account of which, with many remarkable particulars relating to volcanic mountains in the moon, I shall take an early opportunity of communicating to this Society. It differed, however, considerably in magnitude and bright-

FACING PICTURE: This completes the series of four sections of the 4.6-day-old moon. It shows the northern end of the evening crescent, for which the other sections appeared in February, March, and April. It was taken by J. H. Moore and J. F. Chappell with the 36-inch Lick refractor on June 2, 1938. On that day the turning of the moon's spherical surface by libration brought into favorable view formations ordinarily too close to the northwest edge to be well seen. One such relatively unfamiliar feature is the great gray plain, Mare Humboldtianum. It can be found, partly streaked with light, 1½ inches to the right and 3½ inches above the lower left corner. Lick Observatory photograph.

ness; for the volcano of the year 1783, though much brighter than that which is now burning, was not nearly so large in the dimensions of its eruption: The former seen in the telescope resembled a star of the fourth magnitude as it appears to the natural eye; this, on the contrary, shews a visible disk of luminous matter, very different from the sparkling brightness of star-light."

ED. NOTE: In this case, the great observer was mistaken, for it is clear that his "burning volcano" was the interior of the crater Aristarchus, which can readily be seen as a luminous spot on the faintly visible earthlit portion of the moon, when it appears in the western sky shortly after new moon. Aristarchus is often so seen in amateur telescopes. Herschel's 1787 observations were made when the moon was two and three days old, and it was three days old on May 4, 1783.

But it is noteworthy that Herschel, in his preliminary remarks, clearly distinguishes between observation "of the facts as they occur" and inferences from observation. The term "volcano" he uses for convenience. The promised further report to the Royal Society was never published, as if Sir William soon realized his mistake. Perhaps it was this misadventure, early in his astronomical career, that tended to turn Herschel from lunar studies. He never again wrote concerning the moon. Instead, his attention was concentrated on planets, double stars, clusters and nebulae, and the construction of the visible stellar universe—on these studies was established his place as one of the founders of modern astronomy.

REVISED ORBIT FOR EPSILON CETI

The cautious announcement by W. S. Finsen, Union Observatory, South Africa, that Epsilon Ceti had a period as short as 1.59 years (*Sky and Telescope*, June, 1953, page 207) has not been verified by his subsequent observations. Based on numerous measurements of this very close binary between 1951 and the end of 1955, Dr. Finsen's revised orbit has a period of 2.62 years. The orbital eccentricity is 0.30, and the semimajor axis 0.112 second of arc. Practically all of the observations have been made with interferometers; micrometer measurements of this difficult pair have not been reported except with the McDonald 82-inch and the Lick 36-inch refractor.

Planetarium Notes

(Most planetariums give group and special showings by appointment.)

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

SCHEDULE: Monday and Friday (Sept.-June), 3:45 p.m.; Thursday, 7:15, 7:45, 9:00 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BLOOMFIELD HILLS, MICH.: *McMath Planetarium.* Cranbrook Institute of Science, Bloomfield Hills, Mich.

SCHEDULE: Saturday and Sunday, 2:30 and 3:45 p.m. Spitz projector. In charge, James Carmel.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

SCHEDULE: Sunday, 2:00 to 4:30 p.m. Admission free. Spitz projector.

CHAPEL HILL: *Morehead Planetarium.* Univ. of North Carolina, Chapel Hill, N.C.

SCHEDULE: Daily at 8:30 p.m.; also 11 a.m. and 3 p.m. Saturdays, 3 and 4 p.m. Sundays. Zeiss projector. Manager, A. F. Jenzano.

CHARLESTON, W. VA.: *Hillis Townsend Planetarium.* Public Library Building, Charleston, W. Va.

SCHEDULE: Saturday, 11:15 a.m. Admission free. Spitz projector. Director, Louise L. Morlang.

CHEROKEE, IA.: *Sanford Museum Planetarium.* Sanford Museum, 117 E. Willow St., Cherokee, Ia.

SCHEDULE: Monday, 8 p.m. (except August). Admission free. Spitz projector. Director, W. D. Frankforter.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 2-1428.

SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Tuesdays and Fridays, 8 p.m.; Sundays, 2 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

DALLAS: *Dallas Planetarium.* Dallas Museum of Fine Arts, State Fair Park, Dallas, Tex., LO-5663.

SCHEDULE: Saturday, 11 a.m.; Sunday, 3 and 4 p.m. Spitz projector. Director, Mrs. Claudia Robinson.

DENVER: *Denver Museum of Natural History Planetarium.* City Park, Denver, Colo., East 2-1808.

SCHEDULE: Saturday and Sunday, 1-4:30 p.m. Spitz projector.

FT. WORTH: *Charlie M. Noble Planetarium.* Ft. Worth Children's Museum, 1501 Montgomery St., Ft. Worth, Tex., PA-1461.

SCHEDULE: Tuesday through Friday, 4 p.m.; Thursday, 8 p.m.; Saturday, 11 a.m. and 3 p.m.; Sunday, 3 p.m. Spitz projector. Director, William Hassler.

INDIANAPOLIS: *Holcomb Planetarium.* Butler University, Indianapolis 7, Ind.

SCHEDULE: Saturday and Sunday, 4 and 8 p.m. Spitz projector. Director, Harry E. Crull.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 23, Mo., Humboldt 8000.

SCHEDULE: Saturday, 3:00 p.m.; 2nd and 3rd Sundays, 3:00 and 4:30 p.m. Spitz projector. Director, Kenneth W. Prescott.

LANCASTER, PA.: *North Museum and Planetarium.* Franklin and Marshall College, Lancaster, Pa.

SCHEDULE: Tuesday and Thursday, 8 p.m.; Saturday and Sunday, 3 p.m. Admission free. Spitz projector. Director, Herbert H. Beck.

LAQUEY, MO.: *Tarbell Planetarium.* Inca Cave Park, Laquey, Mo.

SCHEDULE: Daily, 1 to 6 p.m., continuous. Spitz projector. Director, E. D. Tarbell.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 27787, Los Feliz Station, Los Angeles 27, Calif., Normandy 4-1191.

SCHEDULE: Wednesday, Thursday, and Friday at 8:30 p.m.; Saturday and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

MINNEAPOLIS: *Science Museum.* Minneapolis Public Library, 1001 Hennepin Ave., Minneapolis 3, Minn.

SCHEDULE: Saturday, 10 a.m. and 2 p.m. Admission free. Spitz projector. Curator of education, Maxine L. Begin.

NASHVILLE: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., 42-1858.

SCHEDULE: Sunday, 2:45, 3:30, 4:15. Spitz projector. Associate curator of education, Burton Ingram.

NEWARK: *Newark Museum Planetarium.* 49 Washington St., Newark 1, N. J., Mitchell 2-0011.

SCHEDULE: Saturday and Sunday, 2:30 and 3:30 p.m. Admission free. Spitz projector. In charge, Ray Stein.

NEW YORK CITY: *American Museum—Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.

SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 1, 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 1, 2, 3, 4, 5, and 8:30 p.m. Zeiss projector. General manager, J. M. Chamberlain.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 1-4300.

SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 4:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.

SCHEDULE: Saturday and Sunday, 3:00 p.m. Spitz projector. Director, Stanley H. Shirk.

PROVIDENCE: *Roger Williams Planetarium.* Roger Williams Park Museum, Providence 5, R. I., Williams 1-5640.

SCHEDULE: Saturdays, Sundays, and holidays, 3 and 4 p.m. Admission free. Spitz projector. Director, Maribelle Cormack.

SAN FRANCISCO: *Morrison Planetarium.* California Academy of Sciences, Golden Gate Park, San Francisco 18, Calif., Bayview 1-5100.

SCHEDULE: Daily (except Monday and Tuesday) at 3:30 and 8:15 p.m.; also at 2 p.m. on Saturdays, Sundays, and holidays. Academy projector. Curator, George W. Bunton.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8:30 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, F. Korkosz.

☆ ☆ *SKY AND TEACHER* ☆ ☆

Sponsored by the
Teachers' Committee of the American Astronomical Society

A WORKSHOP IN THE TEACHING OF ASTRONOMY – II

DURING the 1955 summer session at Cornell University, a workshop for secondary school and college teachers of elementary astronomy was conducted by the writer. In this column for March, two phases of the workshop program were described: the content of school and college curricula in astronomy, and a review of the subject matter of astronomy. Two other aspects of the program are considered in this concluding installment.

Teaching Aids

From a practical point of view, teaching aids formed the core of the workshop. A wide variety of projects, activities, demonstrations and the like were discussed or carried out for the teachers. As they were treated for the most part simultaneously with the review of subject matter, teachers had before them at all times both the goal and the means of its attainment. Frequently, variations of techniques appropriate to several student levels were considered together.

Usually a subject was introduced by a demonstration lecture, followed by a visit to the laboratory, where procedures adapted to individual study were considered. An illustration may be drawn from optics. The passage of light rays through a simple lens was demonstrated on a large scale before the entire class. Similar presentations for compound lenses and mirror systems followed. Then came demonstrations of aberrations so strikingly performed that seventh grade students would easily understand. Finally, the topic was closed with laboratory projects in which each student could investigate for himself the phenomena to which he had been introduced.

The subject of spectroscopy, beginning with a rainbow produced by a model raindrop, was developed in a similar fashion. Advice was offered on how to take advantage of a demonstration that failed for some reason. The dangers, however, of the indiscriminate or careless use of this negative method of teaching were stressed emphatically.

Additional lecture demonstrations used in the workshop include: a. representation of complex optical systems by string or wire models; b. presentation of continuous, absorption, and emission spectra on a large scale; c. demonstration of black-body radiation laws; d. properties of telescopes, including magnification, light-gathering power, resolving power, and field of view; e. observation of a model variable star with an actual photocell; f. a model comet for the illustration of characteristic radiations.

At appropriate opportunities, mention was made of sources of supply for materials, instruments, charts, photographs, slides, and the like. For persons not well acquainted with astronomy, this information meant considerable saving of time, energy, and money, especially since the merits of products from several sources were compared. Samples of most of the items were available, and teachers could judge their suitability for their own classes. Lists of sources, though voluminous, were eagerly studied, for there exist few, if any, general astronomical supply houses comparable to those dealing in biological, chemical, and physical apparatus.

In certain phases of astronomy, particularly the planets, models are useful. Their materials, design, cost, fabrication, and maintenance were treated in detail. Each teacher was required to prepare dimensions for models of the major members of the solar system, relatively correct, and scaled for use in his own classroom. One teacher proposed using colored balls of yarn for the planets; the general fuzziness is realistic, and some major features can be woven into the model. The novice frequently feels that a good model can be made better by adding more features, but the result when viewed from the rear of a large lecture room can be quite confusing. Therefore, models should not be too complex, especially those for coordinate systems.

Since opportunity for originality is essentially unlimited in astronomical model construction, students frequently elect this activity for class projects and for science fairs or contests at all levels. Among the many projects we discussed the following are typical: model of the 200-inch telescope, a laboratory spectroscope, a model spectroheliograph with artificial sun, a star identifier, eclipsing and variable star models, and various forms of tellurometer, a device for demonstrating solar insolation, the seasons, and time.

The importance of frequent observational work was stressed in the March article. While observing programs in secondary schools pose many problems, much can be done by ingenious use of local circumstances. Frequent observations of typical celestial objects during the summer, at Cornell's Fuertes Observatory, helped the teachers plan similar work for their own classes. Special attention was directed to the comparative results with instruments ranging from binoculars to a 12-inch telescope.

Although observational projects are limited in number only by the ingenuity of the teacher, experience has shown that the following are among those most readily adapted to a variety of levels of group or individual effort.

1. Observation of sunspots with a telescope equipped for projection of the sun's image.

2. Charting of the moon's path and the planet's motions on a star chart based on the ecliptic.

3. Visual observations of a variable star to establish its light curve.

4. Construction of a moon map made from telescopic observations, supplemented by photographs.

5. Determination of an observer's latitude by the lengths of shadows in sunlight.

6. Observations of meteors and meteor showers.

Suggestions on carrying out some of these activities have been made in my article, "Making the Most of Astronomy in High School Science," published in *School Science and Mathematics*, December, 1948, page 713.

One could, of course, devote an entire workshop to teaching aids. A collection

The Weisbecker grinding and polishing machine was used by the Cornell group. The ring, shown tipped back, drives the mirror blank across a rotating tool. Stroke and overlap can be accurately controlled. The mirror is weighted to secure the desired contact pressure. Photograph by Richard Sindell.

of directions, drawings, plans, techniques, or in other words a handbook on the teaching of astronomy, would save much time and effort, especially for inexperienced teachers. Would it be useful to teachers of astronomy in general?

In the final analysis, teaching aids, when properly used, can mean the difference between a slow, tedious transfer of ideas from teacher to student and a clear, almost spontaneous, grasp of a concept. However, teaching aids should never become a crutch upon which a teacher may rest an otherwise poor contribution. Demonstrations alone, no matter how brilliantly performed, do not constitute the whole of good teaching.

Constructing a Telescope Mirror

On the premise that a telescope is the best means by which a teacher can create in his students deep and lasting interest in astronomy, we decided to include mirror making in the workshop. Furthermore, a teacher who can make telescope mirrors is in an admirable position to gather about him students interested in learning by doing.

It may be suggested that mirror making is hardly a proper university activity and that an energetic teacher might better learn the techniques on his own time. Generally speaking, secondary school teachers are so loaded with classes that they have little or no time for development work, especially in a technique as difficult as optical fabrication. This portion of the workshop was optional, however, and some members of the class lacked either the time or inclination, but each who undertook the work completed a satisfactory 6-inch mirror of which, it was apparent, he was immensely proud.

All of the work except the last stages of figuring was done by a Weisbecker machine adapted to the Hindle process. I believe that only through machine work is such a program feasible in a strictly limited time. At each stage of the process the translation from machine to hand work was made evident, so that all steps could be duplicated by hand at a more leisurely pace. Simple and elaborate mountings were illustrated by models or actual assemblies. Each teacher paid for a standard 6-inch mirror kit obtainable from a number of suppliers and for aluminizing of the finished mirror by the Evaporated Metal Films Company, Ithaca, N. Y.

It should be remembered that this workshop was an experimental project. There was little to guide it either in content or procedure. Throughout the course particular attention was paid to class reaction, without, however, making it an open issue. The foregoing summary of the project therefore includes ideas originating from the teachers who attended the workshop.

R. WILLIAM SHAW, chairman
Department of Astronomy
Cornell University

NEWS NOTES

By Dorrit Hoffleit

ALL-WEATHER RADIO SEXTANT

Among the new instruments being developed as aids to aerial navigation is the radio sextant, which can observe the position of the sun (and the moon) in the sky by means of its radio energy output, regardless of weather conditions. This device lends itself to use with high-speed navigational computers, such as the one developed by Gene R. Marner (*Sky and Telescope*, February, 1956, page 151). Now, in the December issue of *Navigation*, another member of the Collins Radio Company scientific staff describes both marine and airborne versions of the all-weather radio sextant.

The original model, built for the U. S. Navy, has a 30-inch diameter antenna and operates at 1.9 centimeters. This wave length permits convenient antenna size and is not very subject to atmospheric absorption. The sextant provides good solar tracking in all kinds of weather—in snowstorms, fog, rain, and heavy overcast. Even in violent thunderstorms, with the sun near the horizon, the instrument has not failed to track satisfactorily.

A 24-inch airborne model has also been built, and is illustrated here. It provides a tracking accuracy (probable error) of about two minutes of arc.

But shorter wave lengths would permit even smaller antennas. For instance, at 8.7 millimeters (which lies between atmospheric absorption bands of oxygen and water vapor) an antenna only 12 inches in diameter should yield accuracies aloft comparable to those of larger instruments on the ground. There would be some loss of efficiency in adverse weather, but the most disturbing conditions would be below flying altitudes.

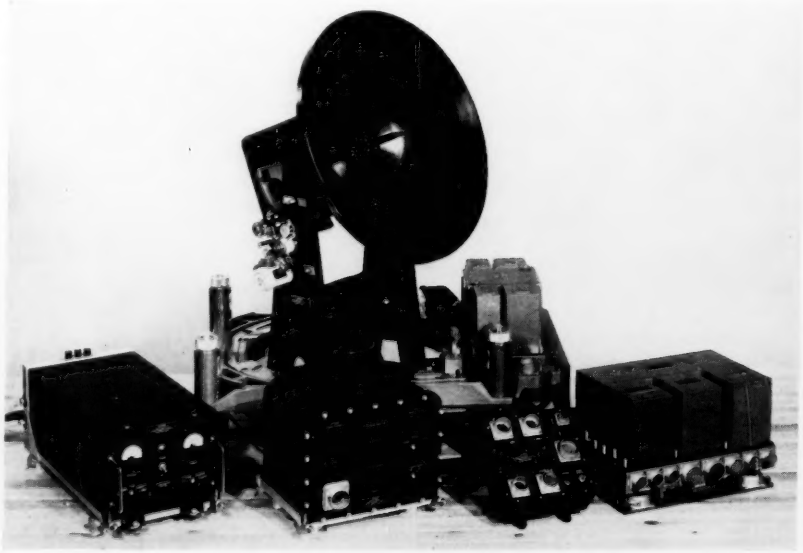
MEGHNAD SAHA DIES

The outstanding Indian astrophysicist, Dr. Meghnad Saha, dean of science at Calcutta University, died on February 16th at the age of 62. With his passing we are reminded how relatively recent have been some of the fundamental advances of astrophysics.

His most important contribution was his theory of ionization in stellar atmospheres, advanced in 1920, when it was still widely thought that the differences in stellar spectra represented mainly differences in the chemical constitutions of the stars themselves. Saha showed, however, that the presence or absence of a particular spectral line depends on the temperature and pressure in the star's atmosphere, these determining the relative numbers of neutral and ionized atoms of each element.

Although the correlation of the spectral sequence with temperature had already been noted, Saha's theory explained why the cool stars of classes *M* and *K* should have complex spectra of many lines, while those of the hot *A* and *B* stars were relatively simple, with few lines. He also helped to show that the spectrum of a giant star differed from that of a dwarf of the same class because a larger fraction of the atoms should be ionized in the distended giant atmosphere than in the denser atmosphere of the dwarf.

At the time of his death, Dr. Saha was



The experimental airborne radio sextant developed by the Collins Radio Company for the U. S. Air Force. It has a 24-inch antenna, but special features require more electronics and controls than would normally be needed for a simple radio sextant. The servo control unit is at the extreme right in the picture. Photograph courtesy Institute of Navigation.

a member of the Indian parliament, director of the Indian Association for the Cultivation of Science, and an editor of *Science and Culture*. In recent years he was active in calendar reform, for in India a bewildering variety of calendars are in current use.

WATSON MEDAL AWARD

At its April meeting in Washington, the National Academy of Sciences will present the James Craig Watson medal to Chester B. Watts, of the U. S. Naval Observatory, for his contributions to astronomy.

At the Naval Observatory, Mr. Watts has been in charge of the 6-inch transit circle since 1934, and his ingenious improvements made this instrument the most efficient of its type in the world for the observation of fundamental positions of the sun, moon, planets, and stars. Recently he designed and supervised the construction of the Naval Observatory's new 7-inch transit circle.

For the past 11 years, Mr. Watts has been engaged in the topographic mapping of the edge portions of the moon, from thousands of photographs. The primary purpose is to allow the moon's profile to be accurately known for any time, so that its irregularities can be allowed for in measuring the moon's position. This project is nearly completed.

MASSES OF STARS OF POPULATION II

Evidence has been accumulating that Population II stars do not follow the usual mass-luminosity relation, as they are less massive for their luminosities than the stars of Population I. For example, some subgiant components of binaries have smaller masses than the sun, even though they are much brighter than it is.

In the *Monthly Notices* of the Royal Astronomical Society (Vol. 115, No. 1, 1955), V. C. Reddish, of the University of London Observatory, computes Population II masses from current theories of stellar structure and evolution, and the pulsation theory of variable stars. Although subject to uncertainties in both theory and observation, his results indicate that the masses increase from about 0.7 of the sun's mass for the brightest dwarfs in globular clusters to 1.0 for the red giants, RR Lyrae variables, blue stars in globular clusters, and the nuclei of planetary nebulae.

ELECTRON NOMENCLATURE

An editorial note in the first issue of *Nuclear Physics* states that it is adopting the word "electron" to apply to an elementary particle of either sign. When it is necessary to state the sign of the electron charge, "positon" and "negaton" will be used. The older term, "electron-positron pair," will be replaced by "electron pair" or by "positon-negaton pair."

IN THE CURRENT JOURNALS

YOUNG STARS, by Adriaan Blaauw, *Scientific American*, February, 1956. "Between the oldest and the youngest stars the age difference is as great as that between a man 100 years old and a baby of two weeks."

THE NEED FOR OBSERVATIONS IN THE OLDER BRANCHES OF ASTRONOMY, ESPECIALLY DOUBLE STARS, by John Jackson, *Monthly Notices* of the Royal Astronomical Society, Vol. 115, No. 2, 1955. "I wish today to examine the position with regard to some of the older branches of activity lest we lose by neglect much of the value of the great heritage which has been handed down to us as the fruit of the labours of our predecessors."

SUNSPOTS AND COMMUNICATIONS, by E. P. Tilton, *Radio-Electronics*, April, 1956. "What will the new cycle hold for us? If we knew exactly, it would cut the fun in half. One thing is sure: the amateur observer who keeps his eyes and ears open will have good opportunities of making contributions to our knowledge of radio propagation in the coming two or three years. And this includes amateurs in the fields of astronomy, radio communication and television dx reception."

SPACE SATELLITES, TOOLS OF EARTH RESEARCH, by Heinz Haber, *National Geographic Magazine*, April, 1956. "Of course, neither humans nor animals will ride the satellite, and I certainly would not hazard a guess when man will challenge space as a passenger in an artificial moon. The problems are enormous. . . ."

CHEMICAL CONVERSION OF SOLAR ENERGY, by Rudolph J. Marcus, *Science*, March 9, 1956. "It is to be hoped that this collation of available facts will encourage a quick and successful attack on this urgent problem of the storage of solar energy."

IDENTIFICATION OF INTERSTELLAR DEUTERIUM NOW DOUBTFUL

At the Jodrell Bank symposium on radio astronomy, held in August, 1955, Russian astronomers announced that the radio spectrum line at 91.6 centimeters wave length, due to interstellar deuterium, had been observed by G. G. Getmanzev and his co-workers at the Gorki Institute of Technical Physics. This finding of heavy hydrogen in the vast spaces between the stars, if confirmed, would be of very great importance, as Dr. B. J. Bok pointed out in his report on the Jodrell Bank symposium (see November, 1955, page 22).

The Russian observation was of a weak absorption dip in the strong radio radiation from the central parts of the galaxy. But V. A. Razin now finds that this dip may have an entirely different cause—polarization of nonthermal cosmic radio emission, as observed by frequency modulation methods. He has planned tests to distinguish between the two explanations, and the original observations are being repeated, according to a letter received by Dr. Bok.

Whether or not interstellar deuterium was actually observed must remain doubtful until these checks are completed.

NUCLEAR PHYSICS

A new monthly journal, *Nuclear Physics*, is being published in Holland under the editorship of Prof. L. Rosenfeld, University of Manchester, England. It will be devoted to experimental and theoretical studies of atomic nuclei, nuclear fields, and the fundamental aspects of cosmic radiation, the last of special interest to astronomers.

The editorial board consists of a representative in each of the 24 countries where nuclear studies are now being actively pursued. Papers will be printed in English, French, or German. The annual subscription for a volume of 700 pages is $15.00, and may be ordered from Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y.

The first number has appeared, containing five technical papers, a progress report by P. H. Fowler on elementary particles, based on a conference at Pisa in June, 1955, and a book review.

ELEMENTS 99 AND 100 NAMED

The names *einsteinium* and *fermium* have been given to the elements of atomic numbers 99 and 100, respectively, with the symbols *E* and *Fm*. They are named in honor of two famous scientists who died recently, Albert Einstein and Enrico Fermi.

Both elements were discovered by Glenn T. Seaborg in radioactive debris from the hydrogen bomb explosion of October, 1952. Since then they have been formed with the University of California's cyclotron at Berkeley, Calif., and in nuclear reactors at Argonne National Laboratory and at the Los Alamos Scientific Laboratory.

All discovered elements through 101 have now been named. The last is called *mendelevium*, in honor of D. I. Mendeleev, originator of the periodic table of the elements, who died in 1907.

ABUNDANCE OF CARBON

In *Leaflet* No. 321 of the Astronomical Society of the Pacific, February, 1956, Paul W. Merrill, Mount Wilson and Palomar Observatories, points out that only five elements exceed carbon in the cosmic abundance of their atoms.

For every carbon atom in the universe, there are three atoms of nitrogen, six of neon, seven of oxygen, 600 of helium, and 10,000 of hydrogen. These are the estimates in a table prepared by Dr. Merrill. He discusses the role of carbon in astronomical objects of all kinds, stars, comets, planetary atmospheres, and in interstellar space.

Amateur Astronomers

Further News About the Miami Convention

PROGRAM DETAILS, exhibit plans, and other arrangements are virtually completed for the Astronomical League convention at Miami, July 2-5. See the April issue of *Sky and Telescope*, page 262, for details of registration and other general information.

Ample space will be provided for displaying exhibits at the convention headquarters, the McAllister Hotel. Telescopes, models, and photographs are desired. Tyrus T. Tripp, 1520 Ponce de Leon Blvd., Coral Gables, Fla., chairman of the exhibits committee, should be advised what exhibits are being shipped, how much space is required, and the value of the material for insurance.

After the convention closes, many delegates will travel to Cuba to visit the National Observatory at Havana, on the invitation of its director, Dr. Carlos Millas. Outstanding Cuban amateurs will meet their friends from the United States, and a personal invitation has been extended by Dr. Miguel Mery to visit his new observatory, the largest in Cuba, which has a 24-inch Fecker reflector.

The accompanying tentative schedule of the convention includes the titles of papers that were placed on the program up to March 30th.

Sunday, July 1

2:30 to 5:30 p.m.	Council meeting.
8:00 to 10:00 p.m.	Registration, McAllister Hotel lobby; informal gatherings; setting up of exhibits.
9:30 to 11:00 p.m.	Council meeting.

Monday, July 2

9:00 to 10:30 a.m.	Registration (and throughout the day), McAllister Hotel lobby.
10:30 a.m. to noon	*Opening Convention Session.* Welcome by the mayor of Miami. Roll call of societies. Reports of officers, nominating committee, and section chairmen.
1:30 to 3:00 p.m.	*Lunar and Planetary Session.* Chairman: Dr. James Q. Gant, Jr., Washington, D.C. Papers: John P. Bagby, "The Holpuch Satellite Ring." Rolland R. LaPelle, "The Moon—Metallurgical Effects Observed in Vacuum." David P. Barcroft, "The Moon and the Amateur." H. P. Wilkins, "On the Minute Lunar Features." W. A. Calder, "The Reflectivity of the Moon." Patrick Moore, "Venus—How the Amateur Can Help." Walter H. Haas, "Mars." Thomas A. Cragg, "The Story of Saturn." Owen C. Ranck, "Observations of Mercury."
3:00 to 3:30 p.m.	Group photograph.
3:30 to 5:30 p.m.	*Frontiers of Astronomy.* Chairman: Dr. H. Franklin Williams, vice-president and director of community affairs, University of Miami. Address by Dr. Harlow Shapley, Harvard Observatory, "The Borders of Astronomy."
7:00 p.m.	Field trips to U. S. Naval Observatory Time Station, Gulfstream Astronomical Association Observatory at University of Miami, and Southern Cross Observatory at Junior Museum of Miami.

Tuesday, July 3

8:30 to 9:30 a.m.	Meeting of the Southeast Region.
9:30 to 10:45 a.m.	*Observing Session.* Chairman: Russell C. Maag, Sedalia, Mo. Papers: James C. Bartlett, Jr., "The Nature of Sunspots." Matt F. Taggart, "Sunrise Phenomena." John Farrell, "Meteorites." Harry Bondy, "Solar Observing in the IGY Program."
11:00 a.m. to noon	*Business Meeting.* Election of officers. Reports of regional chairmen.
1:30 to 4:30 p.m.	*Zero Minus One Year.* Chairman: G. R. Wright, Silver Spring, Md. Papers: Armand N. Spitz, "Visual Satellite Tracking." Dr. Fred L. Whipple, "The Artificial Satellites." Dr. J. A. Hynek, "Satellite Observing Methods."
6:30 p.m.	*Convention Banquet.* Toastmaster: James J. Marshall. Guest speaker: Dr. Harlow Shapley, "Fun with Planet No. 3." Presentation of Astronomical League award.
9:00 p.m.	*Star Party.* Telescope observations in Bayfront Park.

Wednesday, July 4

9:30 to 11:00 a.m.	*Panel Discussion on Club Programs.* Chairman: Arthur P. Smith, Jr., Miami, Fla. Papers: Mabel Sterns, "Highlights in the League's First Ten Years." Armand N. Spitz, "Community Relations for Astronomy Clubs." Charles A. Federer, Jr., "A Club Is as Good as Its Leaders." Thomas L. Gibson, "The Noble Telescope Library."
10:45 a.m. to noon	*Junior Session.* Chairman: Clarence E. Johnson, Schenectady, N. Y.
1:30 to 3:00 p.m.	*Instrumentation.* Chairman: Tyrus T. Tripp, Coral Gables, Fla. Papers: Robert E. Cox, "The Problem of a Uniform Abrasive Scale." George H. Lutz, "Metal Mirrors."
3:00 to 4:00 p.m.	*Final Meeting.*

NORTH CENTRAL CONVENTION

The North Central Region of the Astronomical League will hold its tenth annual convention on Saturday, May 19th, at Beloit, Wisc., in the First Presbyterian Church, Prospect and Public Aves., adjacent to Beloit College.

Edward Halbach will report on the 1955 annular solar eclipse expedition to Africa, and Ralph Buckstaff will give up-to-date information on the sunspot cycle.

Advance registrations may be made with Earl McGinnis, 718 St. Lawrence Ave., Beloit, Wisc. The fee until May 12th will be $1.00; after that date, it will be $1.50.

MIDDLE EAST CONVENTION

As announced in April, the principal speech at the Middle East Region's convention in Washington, D. C., will be given by Dr. Joseph Kaplan. It will be preceded by a dinner at the Greystone Restaurant, for which reservations may be made with Mrs. Lillian R. Gregor, 3937 S St. S.E., at $2.25 per person. Mrs. Gregor will also accept in advance the convention registration fee of $1.00.

At the opening session on Friday evening, May 4th, two color films will describe the application of calculating machines to scientific research, including astronomy, and to business and industry. The papers on Saturday will include a talk by Adam L. Ott on his experiences with a solar eclipse expedition, a discussion of the properties of the Questar telescope by Ellis Marshall, and the story of tektites by Ralph Stair.

On Sunday morning, May 6th, the satellite observing committee of the Astronomical League will conduct a session on the artificial satellite tracking program for amateurs. A workshop conference on organizing and directing junior groups, as well as a session for juniors, complete Sunday's program, with adjournment at noon.

"Astronomy Special" to Miami Convention

AMATEURS in the Northeast and the Middle Atlantic states who will attend the Miami convention of the Astronomical League in July may wish to travel by train in a group excursion being sponsored by *Sky and Telescope* and led by the editor, Charles A. Federer, Jr.

Twenty-four hours of congenial travel each way at economical summer rates are assured in the air-conditioned reclining-seat coaches of the East Coast Champion, crack New York-to-Miami flyer of the Atlantic Coast Line. If enough persons take part, the "Astronomy Special" will have a coach to itself, and informal get-togethers to talk astronomy will be the order of the journey. Amateur astronomers traveling by Pullman on the same train will be invited to visit the coach and get acquainted with their fellows.

Carrying amateurs from New England and New York state, the Champion will leave New York's Pennsylvania Station on Saturday afternoon, June 30th, at about 2:20 p.m. Eastern standard time (subject to slight change in summer time tables). Stops will be made in New Jersey at Newark and Trenton, while Pennsylvania amateurs will board the train at 30th St. Station, Philadelphia, at about 4 o'clock. Other stops are scheduled for Wilmington, Baltimore, and Washington, D. C., and it is expected that some astronomers will join the party at Richmond, Va., about 9 o'clock in the evening.

Arriving directly in Miami on Sunday, July 1st, about 2:20 p.m., where the city will be on standard time, the group will travel together to the McAllister Hotel, site of the convention headquarters. There will be ample time for a swim or a walk on the beach before the first informal event on the convention program.

Most of the group will start the return trip from Miami on Saturday, July 7th, also on the Champion, at about 10:00 a.m., arriving in New York Sunday morning. Boston travelers will reach home that afternoon. This return date allows two full days in Miami or visits to other parts of Florida after the official close of the convention on July 4th, but the 30-day tickets may be used for individual return earlier or later than July 7th.

The round-trip summer fares, which go into effect May 1st, are, from New York to Miami and return, including federal tax, $67.77; from Philadelphia, $61.11; and from Washington, $51.10. All coach seats on the Champion are reserved, for a surcharge of $1.10 each way, adding a total of $2.20 to the round-trip cost.

Tickets may be purchased at any travel bureau or railroad station. When paying for the reserved seat on the Champion, be sure to tell the agent to request it in the coach carrying the "Astronomy Special." These seats will be allotted at the Atlantic Coast Line's reservations headquarters in New York, 16 East 44th St., for both the southbound trip on June 30th and the return trip on July 7th.

Attendance at the convention is open to everyone. If you are definitely participating in the coach excursion, or contemplate doing so, notify the editor of *Sky and Telescope* as soon as possible. Your registration with him will aid considerably in planning the trip and in estimating the number of seats to be held for the "Astronomy Special." Groups traveling to points on the Champion's route from other places should investigate the possibility of additional savings; for instance, about $4.00 each can be saved if 10 or more persons travel together by rail from Boston to New York, and return within 10 days.

Sky and Telescope can assume no responsibility, however, for the procurement of seat reservations, nor can it guarantee the above fares and schedules.

Northeast Convention

Dr. C. W. Gartlein of Cornell University will be the banquet speaker at the Northeast regional convention of the Astronomical League, to be held at Colgate University, Hamilton, N. Y., May 18-20. His topic will be auroral studies during the Geophysical Year. Another speaker will be Paul Stevens, who will discuss next year's transit of Mercury.

Other papers will concern the September opposition of Mars, and amateur observations for the artificial satellite program. Amateur and professional instruments, globes, books, and charts are to be exhibited. Colgate Observatory will also be open for observing on Friday and Saturday nights.

The Utica Amateur Astronomers will be host to the convention. Co-chairmen are Richard L. Carner, president of the Utica club, and Dr. Harold Lane, of the Colgate University physics department.

Stellafane Meeting

This year's Stellafane meeting will be held at Breezy Hill, Springfield, Vt., on August 11th—the first Saturday after the month's new moon. The Springfield Telescope Makers and the Amateur Telescope Makers of Boston are cosponsors of the event.

In the instrument exhibition, a regular part of the Stellafane program, recognition will be given to all types of telescopes in this year's awards, but advanced designs—closed-tube reflectors, compound and catadioptric systems—will be judged in a special class.

A national program of amateur observations of artificial satellites will be discussed. Rich-field telescopes are suited to the purpose, and their use will be described.

Plans are being arranged for a variety of informal discussions with men who are specialists in their fields. The advanced catadioptric systems offer promise of unusual interest, and a round-table talk will be held on this subject.

Room reservations, if desired, can be made through Mr. Merryfield of the Hartness House, Springfield, Vt. More information about this meeting can be obtained by writing to James W. Gagan, ATM's of Boston, Harvard College Observatory, Cambridge 38, Mass.

Mid-States Convention

The Central Missouri Amateur Astronomers will be the host society to the Mid-States Region of the Astronomical League at the Morrison Observatory, Central College, Fayette, Mo. The convention will be held on the weekend of June 15-17.

Accommodations will be provided on the Central College campus. The program is under the supervision of the St. Louis Astronomical Society.

Further information may be had from Jo Williamson, 344 Howard Payne, Central College, Fayette, Mo.

Chant Medal Winner

Frank DeKinder, director of observations for the Montreal Centre of the Royal Astronomical Society of Canada, was awarded the Chant medal at the society's annual meeting in Toronto on February 17th.

The award was established in 1940 by the society in commemoration of Dr. C. A. Chant, and is given annually to an outstanding Canadian amateur astronomer.

This Month's Meetings

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory, May 18, Dr. Albert E. Whitford, Washburn Observatory, "Analysis of Radiation from Distant Galaxies."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Lone Star Gas Co. auditorium. May 28, astronomical film.

Detroit, Mich.: Detroit Astronomical Society, 2:30 p.m., State Hall, Wayne University. May 13, Dr. Everett R. Phelps, "The Planet Mars."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. May 16, annual meeting.

St. Louis, Mo.: St. Louis Astronomical Society, 8 p.m., Academy of Science. May 18, Dr. Harold Bulger and A. C. Calloway, "Mars."

Springfield, N. J.: Amateur Astronomical Society of Union County, 8 p.m., Regional High School. May 25, symposium, "Life on Other Planets."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. May 5, Dr. Joseph Kaplan, University of California, "The International Geophysical Year and the Space Frontier."

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 94th meeting of the American Astronomical Society at Columbus, Ohio, in March. Complete abstracts will appear in the Astronomical Journal.

Does the Galaxy Have a Gaseous Corona?

The interstellar gas clouds that occur within the spiral arms of the Milky Way galaxy are mostly hydrogen, with an average density of one atom per cubic centimeter. Recently, the question has been raised of whether there is also even more rarefied gas between the spiral arms, as well as at great distances above and below the central plane of the galaxy.

The Russian astronomer I. S. Shklovsky suggested in 1952 that much of the cosmic radio noise received on earth might originate in an extended spherical corona surrounding the galaxy. The neighbor galaxy M31, in Andromeda, seems to have a spherical corona some 10,000 parsecs in radius which is the source of about two thirds of the total energy radiated by that system at a wave length of 3.7 meters.

Lyman Spitzer, Jr., Princeton University Observatory, pointed out a further reason for suspecting the existence of such a gaseous envelope. Numbers of ordinary interstellar clouds are observed 500 and more parsecs above the galactic plane, where they should be highly unstable unless embedded in a gaseous medium. The probable properties of a gaseous corona have been worked out in some detail by Dr. Spitzer.

Although consisting of ionized gas of very low density, containing only about 15 electrons per cubic foot, this extensive corona would have a very high temperature, about a million degrees absolute. But if heated to three million degrees, the particles would move so rapidly they would easily escape from the gravitational control of the galaxy as a whole. Extending perhaps 8,000 parsecs from the galactic plane, the corona would have a total mass of about 100 million suns.

With its extremely high temperature, this interstellar corona should emit the same type of radiation as the corona of the sun, but the rate of emission per atom would be reduced in about the same ratio as that of the densities of the two mediums. This factor is roughly 10^{-11}, and the galactic corona emission would be very weak and entirely unobservable. Only by its effect on the light of other galaxies might the galactic corona be detectable, but the absorption lines thus produced would lie in the far ultraviolet shorter than 2000 angstroms.

Even more speculatively, Dr. Spitzer suggested that condensation of cool matter from the galactic corona might account for formation of new spiral arms of the galaxy as the old ones dissipate. Material ejected at high speed from the stars themselves might provide the energy to keep the corona at a temperature of a million degrees. Otherwise, radiative cooling would use up the assumed thermal energy in about a billion years. Were the corona nearly three million degrees hot, however, radiative cooling would be unimportant, and a gaseous envelope at such a temperature might have existed since the galaxy was formed.

Orion Nebula Spectrum

New information about the physical properties of the Orion nebula has resulted from photoelectric measurements of the brightnesses of more than 30 emission lines in its spectrum, by W. Liller and L. H. Aller, University of Michigan Observatory. They fed light of the nebula through a grating monochromator attached to the 24-36-inch Curtis Schmidt telescope. The resulting spectrum, with a dispersion of 32 angstroms per millimeter, was scanned by an EMI 6685 photomultiplier tube between 3200 and 6200 angstroms, while a Farnsworth 16-PM-1 photomultiplier was employed from 6200 to 12,000 angstroms, in the infrared.

The observations were of a region 15 seconds of arc east of the Trapezium, and agree well with the earlier photographic measurements by A. B. Wyse. This area has an electron temperature of 9,600° absolute, and there are about 7,000 electrons per cubic centimeter. From the intensities of the spectral lines, the element sulphur appears to be some seven times more abundant, relative to other atoms, in the Orion nebula than in the atmospheres of stars.

Early History of Radio Astronomy

The background of Karl G. Jansky's historic discovery of radio emission from the galaxy was described to the American Astronomical Society in a dinner speech by his older brother, C. M. Jansky, Jr.

In 1928, Karl Jansky at the age of 23 joined the staff of the Bell Telephone Laboratories, and was given the task of studying static and interference noises affecting transoceanic radiotelephone circuits. While some of this work concerned long wave lengths around 4,000 meters, he soon turned to 14.6 meters, at that time a relatively unexplored region of the electromagnetic spectrum, instrumentation for which posed new problems.

About March, 1929, he began the design of a 14.6-meter rotatable, directional antenna and receiver system. This was erected in 1930 at the Bell Laboratories' field station at Holmdel, N. J. There Jansky carried out lengthy systematic observations of 14.6-meter static to find how it depended on time and direction.

Much of the static was traced to nearby and distant thunderstorms, but part of it varied in intensity with sidereal time, indicating an extraterrestrial origin. In April, 1933, Jansky was able to announce that the source was located roughly at right ascension 18^h, declination $-10°$—nearly in the direction of the center of the Milky Way galaxy.

It is from these first successful observations by Karl Jansky that radio astronomy developed; shortly after his death in 1950, it became a major branch of astronomy.

Relativity and Planetary Motions

The motions of the inner planets afford an important test of the general theory of relativity. For each orbit, the longest diameter is slowly turning counterclockwise, but relativity theory predicts a slightly faster shift than Newtonian gravitation calls for. This difference, expressed in shift of the perihelion per century, amounts to 43.03 seconds of arc for Mercury, 8.6 for Venus, and 3.8 for the earth.

At the U. S. Naval Observatory, R. L. Duncombe has made a detailed examination of the observational evidence for the relativity effect in these three planets. He finds that the observed motion of the perihelion per century exceeds the gravitationally predicted value by 43.11, 8.4, and 5.0 seconds, respectively. The close agreement between these two sets of numbers is a fresh verification of the correctness of relativity theory.

The difference between the relativistic and gravitational shifts of the perihelion is greater the closer a planet is to the sun, and is larger for more eccentric orbits. The relativistic effect had not hitherto been established for Venus, partly for these reasons, and also because the perihelion point of the nearly circular orbit of Venus is difficult to determine accurately from observations.

Infrared Spectrum of S Ursae Minoris

In the infrared spectra of late M-type variable stars, a broad absorption band near wave length 10,500 angstroms was discovered in 1947 by G. P. Kuiper and his co-workers. Despite the conspicuousness of this feature, the molecule causing it has not been identified.

Using the Curtis Schmidt telescope of the University of Michigan, Freeman D. Miller has studied the behavior of the 10,500 band in the long-period variable S Ursae Minoris over the 324-day cycle of its light changes. When this star is at maximum brightness, its spectral type is about *M6*, and the infrared band is

rather inconspicuous. But at minimum light, when S Ursae Minoris has a spectral class between *M*8, and *M*9, the 10,500 feature is so strong as to dominate this part of the star's spectrum.

This is in accord with Dr. Miller's observations of other stars. The band is absent from the spectra of stars hotter than about *M*6, and it is increasingly more conspicuous in stars of later spectral type.

Algol as a Triple Star

It has been known for a long time that the two stars comprising the eclipsing binary Algol, whose period is 2.87 days, are in orbital motion relative to a third star, in a revolution period of 1.8 years. This fact was inferred from variations in the period, proper motion, and radial velocity of the eclipsing pair.

The third star has now been observed directly with some certainty, by A. S. Meltzer, of Princeton University Observatory, on three spectrograms taken with the 100-inch Mount Wilson telescope. While the bright primary component of Algol was in eclipse, he noted additional lines in the red part of the spectrum. These relatively sharp lines, typical of an *F*-type star, did not change in wave length as they should, had they arisen from the secondary star and been affected by its revolution around the primary.

Hence, the Princeton astronomer concluded that the sharp lines originated in the third star. Combining his observations with previously known data on the Algol system, he found that Algol C has a visual absolute magnitude of +3.6, an *F*5 spectrum, and a mass slightly less than the sun's. For Algol B these values are +4.22, *G*9, and 0.62 the sun's mass. Algol A, the principal component, has an absolute magnitude of +0.38, a spectral class of *B*8, and 2.32 times the sun's mass.

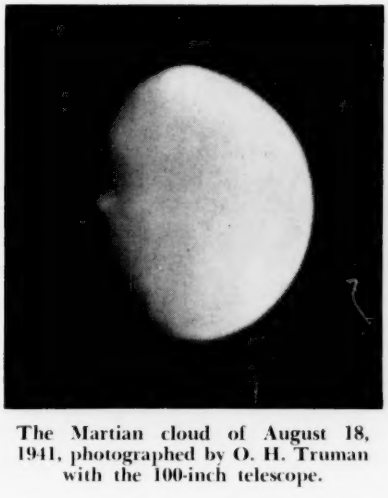
Recurrent Martian Clouds

A tendency for clouds in the atmosphere of Mars to recur for decades over one part of the planet's surface has been discovered by Dean B. McLaughlin, University of Michigan Observatory. His evidence for this is from photographs taken between 1926 and 1954.

The region in question is that of the strongest knot in the peculiar W-shaped cloud formation photographed in blue light during the 1954 opposition. Pictures from Mount Wilson Observatory, by Pettit and Richardson, and from South Africa, by E. C. Slipher, were reproduced in *Sky and Telescope*, July, 1955, page 362. This knot was in Martian longitude 120°.6, latitude −10°.8, near the oasis Arsia Silva.

Dr. McLaughlin noticed a cloud in nearly the same position on a blue photograph taken by O. H. Truman with the 100-inch Mount Wilson reflector on August 18, 1941; this picture is reproduced here. This bright, dense cloud was about 350 miles in diameter, with its center near the large oasis Phoenicis Lacus; the cloud is at longitude 115°.8, latitude −17°.0, partly overlapping the area covered by the strongest knot of the W of 1954.

Searching further, the Michigan astronomer found that other clouds over this



The Martian cloud of August 18, 1941, photographed by O. H. Truman with the 100-inch telescope.

part of the planet were photographed in July, 1939, by W. H. Wright with the Lick Observatory 36-inch reflector, and in October, 1926, by Wright and F. E. Ross. Coincidence with the strongest knot of the W is quite marked.

It appears that these recurrent clouds were produced by some mechanism associated with a fixed location on the planet's surface. Dr. McLaughlin believes that the explanation may lie in his hypothesis of volcanic activity on Mars (see page 372 of the September, 1954, issue).

Brightness and Color of the Extragalactic Sky

W. A. Baum, Mount Wilson and Palomar Observatories, suggested measuring the brightness and color of the total light reaching the earth from outside our galaxy. This light is so much fainter than the airglow of the night sky that it cannot be studied from the earth's surface, but it should be observable from an artificial satellite.

Important cosmological conclusions could result from such observations. For example, the brightness and color of the extragalactic sky will depend upon how far the universe of galaxies extends beyond the limits of present telescopes. If observations of brightness were made at several wave lengths, we might learn about the occurrence of stars in intergalactic space. There is already some evidence that galaxies are not as sharply bounded as once thought, but may spread out indefinitely and even blend into one another (*Sky and Telescope*, March, 1956, page 204).

"Fortunately," said Dr. Baum, "the instrument required to make these observations can be extremely simple and compact. The proposed design includes a small lens, tiny color filters, a red-sensitive photomultiplier, a radium-paint button for standardization, and a circuit about the size of a pack of cigarettes. Total power requirements of the system are less than a watt. The signal output, which is fed to a telemetering channel, consists of a stream of pulses whose frequency is an accurate measure of the light received."

The instrument payload of the first artificial satellite will be so small, however, that carrying out even as compact an experiment as Dr. Baum proposes would raise serious practical problems.

PENNSYLVANIA DEDICATION

The Flower and Cook Observatory of the University of Pennsylvania will be dedicated on June 11th and 12th. This new location of the 28½-inch reflector and the 15-inch horizontal refractor is 20 miles west of Philadelphia, well removed from city lights and smoke.

At the ceremonies, Dr. Fred L. Whipple, Harvard Observatory, will give a popular lecture on the satellite project. There will be a two-day symposium on present and future uses of telescopes of 40 inches and smaller aperture, covering electronic and other techniques. Both amateur and professional astronomers are invited to the lecture and symposium.

NOTICE TO SUBSCRIBERS

Increased manufacturing and distribution costs make necessary a rise in the subscription price to *Sky and Telescope*. This will not take effect, however, until the issue of July, 1956, and will not apply to astronomical societies that provide the magazine as a privilege of membership until January 1, 1957. Current subscribers may extend their subscriptions at any time until July 1, 1956, for as much as three years at the rates shown at the foot of page 291 of this issue.

The new rates will be $5.00 per year in the United States and possessions; $9.00 for two years; and $13.00 for three years. Add $1.00 per year for Canada, Mexico, and all countries of the Pan-American Postal Union, making the total subscription $6.00 for one year; $11.00 for two years; and $16.00 for three years. Add $2.00 per year for all other foreign countries, making the total subscription $7.00 for one year; $13.00 for two years; and $19.00 for three years. Canadian and foreign remittances should be made in United States currency.

The single copy price of *Sky and Telescope* is now 50 cents. Back issues are available for most numbers at 50 cents each. Issues earlier than 1952 may be ordered from Midtown Magazine and Book Shop, 1105 Sixth Ave., New York 18, N. Y. Newsdealers wishing to carry *Sky and Telescope* may order it from Eastern News Co., 306 West 11th St., New York 14, N. Y.

KEY TO PHOTOGRAPH

The numerical key for this group photograph is simplified to show the last-name initial of each person: to identify a familiar face, it is necessary only to peruse the names with that initial letter in the alphabetical list. The presence or absence of persons known by name can be checked quickly in the alphabetical list.

1 N, 2 F, 3 M, 4 K, 5 H, 6 H, 7 W, 8 K, 9 H, 10 T, 11 G, 12 S, 13 A, 14 M, 15 H, 16 K, 17 C, 18 S, 19 D, 20 A, 21 W, 22 D, 23 B, 24 G, 25 M, 26 M, 27 M, 28 M, 29 F.

30 unidentified, 31 L, 32 W, 33 B, 34 M, 35 H, 36 P, 37 H, 38 B, 39 G, 40 P, 41 C, 42 B, 43 K, 44 R, 45 H, 46 M, 47 Z, 48 S, 49 S, 50 C, 51 S, 52 G, 53 A, 54 W, 55 F, 56 C, 57 R, 58 S, 59 W.

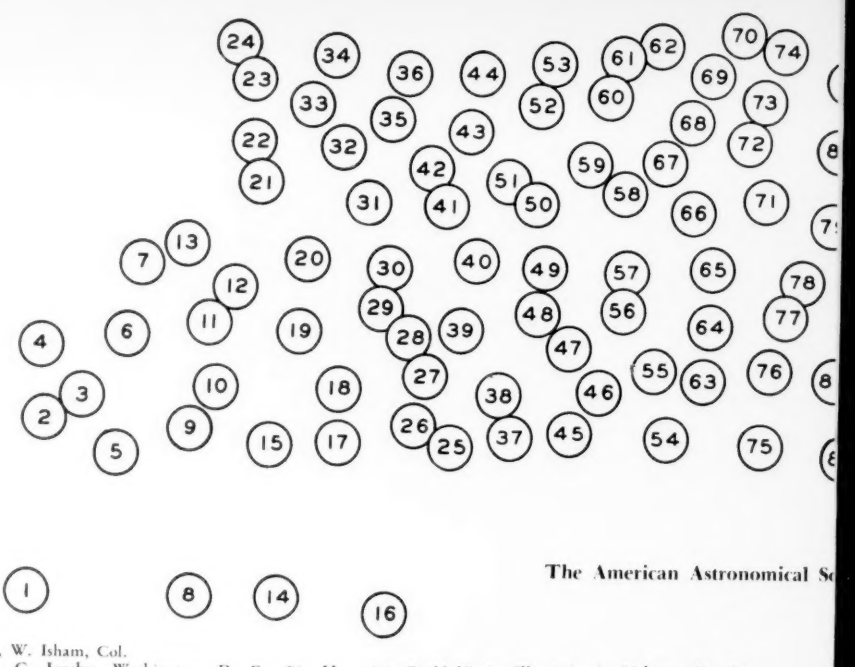
60 P, 61 P, 62 D, 63 T, 64 K, 65 L, 66 J, 67 M, 68 C, 69 B, 70 D, 71 J, 72 F, 73 I, 74 W, 75 W, 76 B, 77 B, 78 G, 79 K, 80 G, 81 D, 82 S, 83 U, 84 F, 85 S, 86 R, 87 D, 88 O, 89 S.

90 M, 91 R, 92 J, 93 R, 94 H, 95 N, 96 E, 97 O, 98 J, 99 M, 100 M, 101 M, 102 S, 103 H, 104 G, 105 C, 106 E, 107 R, 108 V, 109 H, 110 M, 111 H, 112 H, 113 P, 114 D, 115 W, 116 U, 117 V, 118 M, 119 S.

120 W, 121 R, 122 E, 123 M, 124 P, 125 M, 126 E, 127 R, 128 H, 129 B, 130 A, 131 M, 132 L, 133 K, 134 L, 135 Z, 136 B, 137 D, 138 C, 139 R, 140 S, 141 P, 142 S, 143 M, 144 F, 145 M, 146 R, 147 F, 148 S, 149 B.

150 H, 151 C, 152 D, 153 B, 154 O, 155 K, 156 W, 157 W, 158 H, 159 P, 160 S, 161 S, 162 K, 163 M, 164 H, 165 K, 166 K, 167 W, 168 H, 169 S, 170 V, 171 L, 172 F, 173 H, 174 T, 175 S, 176 unidentified, 177 E, 178 B, 179 B.

180 C, 181 S, 182 H, 183 G, 184 S, 185 E, 186 T, 187 C, 188 O, 189 K, 190 L, 191 F, 192 S, 193 W, 194 M, 195 B.



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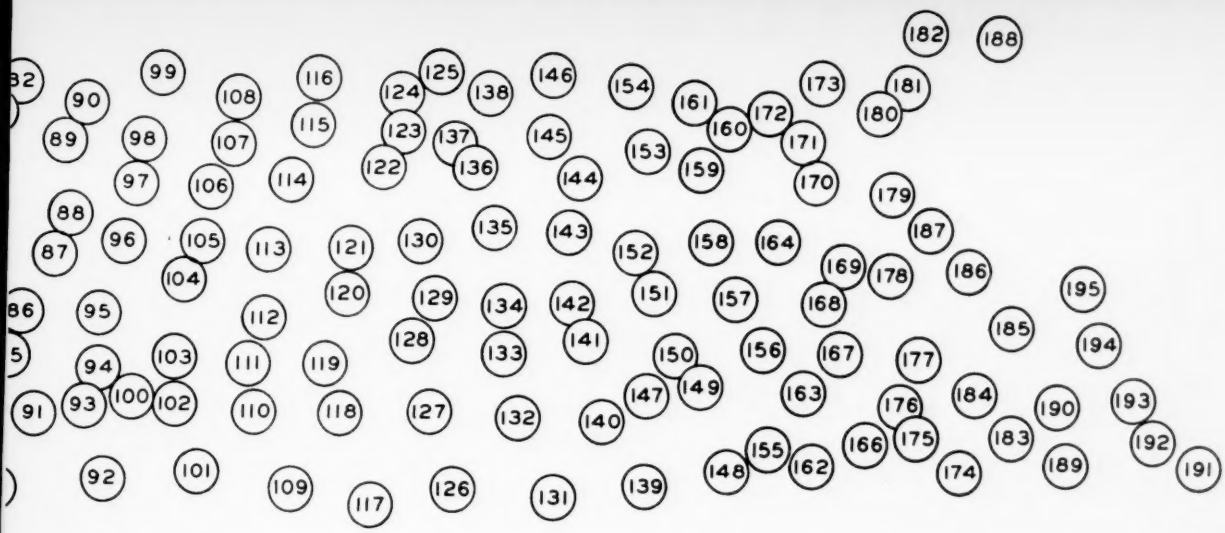

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86, E. Rabe, Cin; 93, J. Raimond, The Hague, Holland; 91, Mrs. Raimond; 44, Miss M. Risley, Randolph-Macon; 139, W. Roberts, HA; 146, L. Robinson, Wright-Patterson Air Force Base; 107, M. Rogers, Ill; 127, J. Rogerson, MWP; 121, Miss N. Roman, NRL; 57, P. Routly, Pomona.

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135, L. Zechiel, OS; 47, H. Zirin, HA.

30, unidentified; 176, unidentified.

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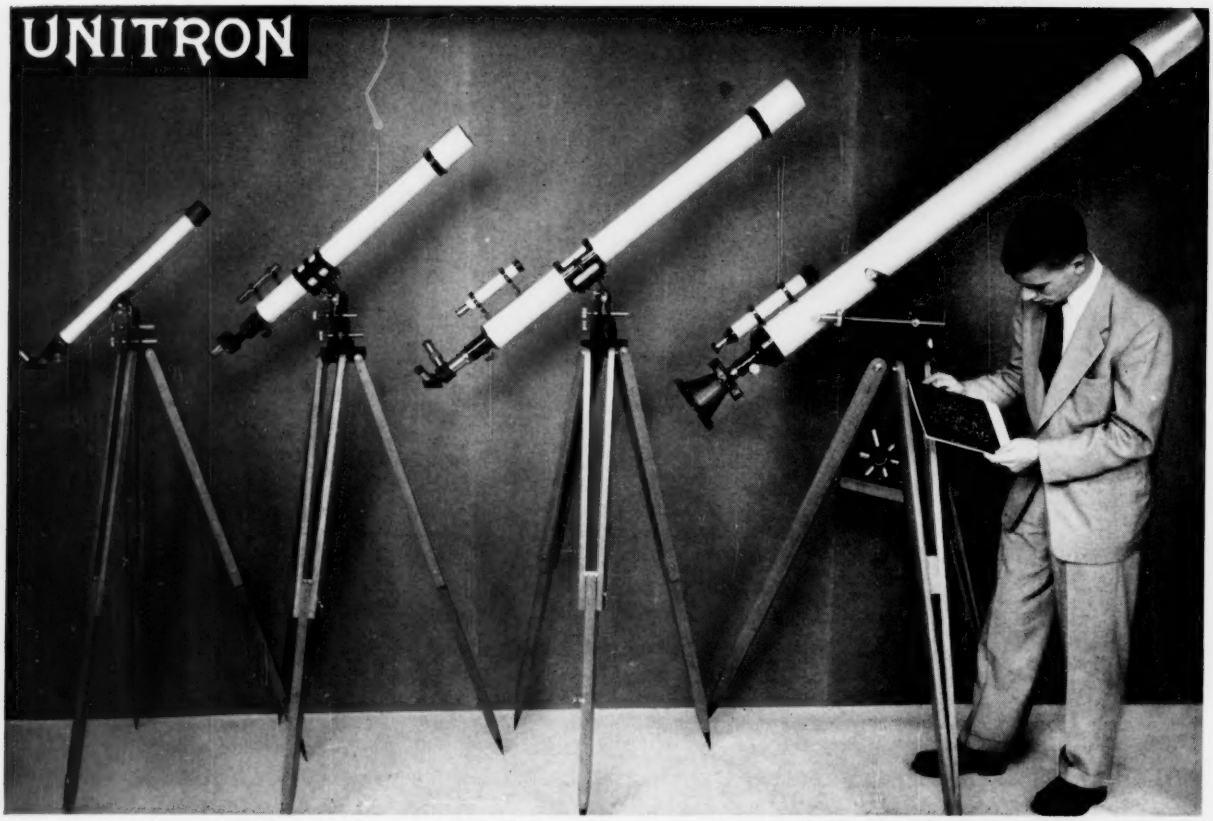
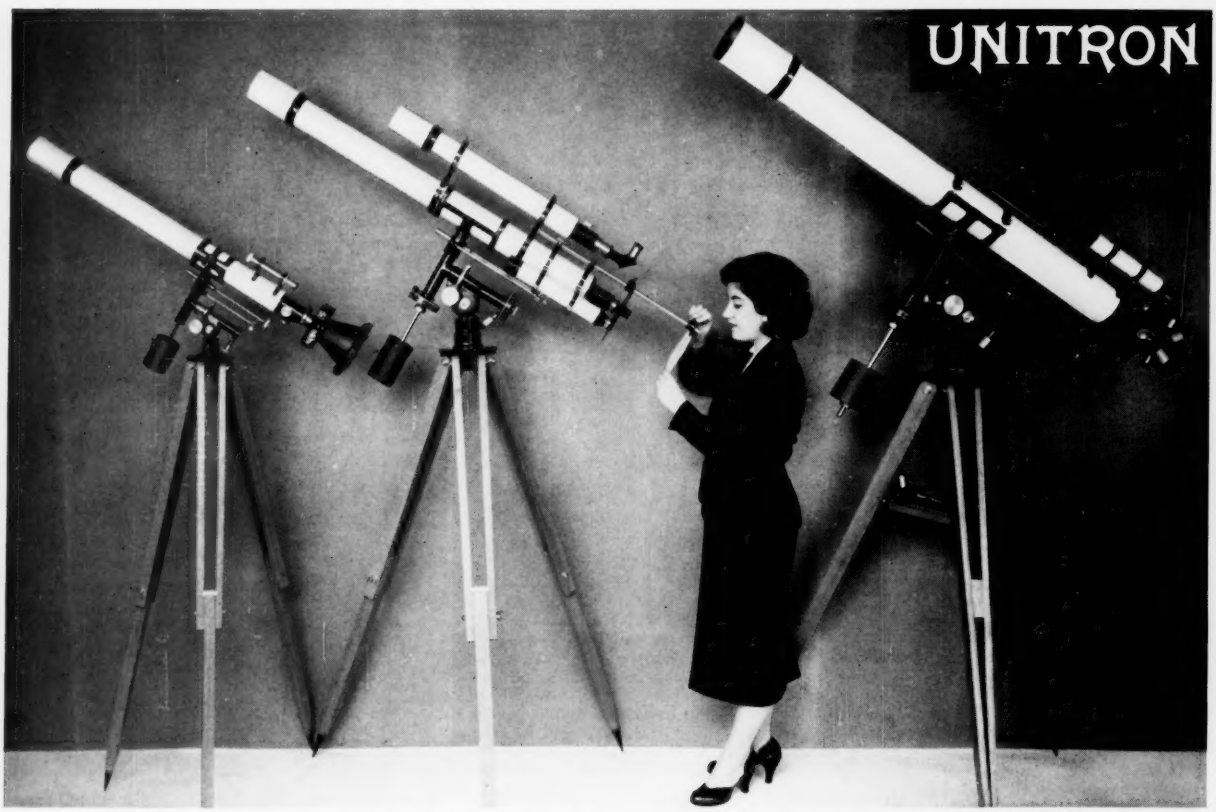


UNITRON Altazimuth Refractors: left to right, 1.6″ (with star diagonal), 2.4″ (with erecting prism system), 3″ (with DUETRON double eyepiece), and 4″ (with astro-camera and with UNIHEX on the shelf).



UNITRON Equatorial Refractors: left to right, 2.4″ (with astro-camera), 3″ Photo-Equatorial (with sun screen), and 4″.

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How to Lose Friends and Alienate Astronomers

To each of the old friends on our mailing list, we should like to say that **you**, personally, were not the only one who failed to receive your copy of the new UNITRON Catalog on time. We hope you will accept our apology for the tardy mailing which was caused by an unforeseen printing delay. Now that you have received your copy, we think you will agree that it was well worth waiting for. Plenty of catalogs are now on hand and new requests will be processed the same day as received.

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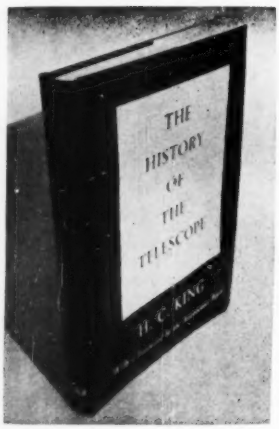

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BOOKS AND THE SKY

VISTAS IN ASTRONOMY

Volume I

Arthur Beer, editor. Pergamon Press, London, 1955. (Western Hemisphere distributors, Sky Publishing Corporation, Cambridge, Mass.) 776 pages. $28.00.

THIS excellent, attractive, weighty, and long-awaited book is the first of two volumes edited by Dr. Beer and dedicated to F. J. M. Stratton, emeritus professor of astrophysics in the University of Cambridge. This first volume contains eight papers on co-operation and organization, 12 on history and philosophy, 10 on dynamics, 13 on theoretical astrophysics, 20 on instruments, nine on radio astronomy, and 20 papers on solar physics.

The second volume, whose publication date has not been announced, will cover the fields of solar-terrestrial relations, geophysics, the planetary system, stellar astronomy, photometry, spectroscopy, spectral peculiarities and novae, galaxies, cosmogony and cosmology, and will include a name and subject index for both volumes.

The purpose of this book is to present original articles and reviews, reflecting fully and critically the present situation and recent advances in astronomy and related fields. The editor suggested to each author a length of about 2,500 words, of which the first few hundred were to be a statement of the problem and a brief summary of previous work, while the concluding paragraphs were to be devoted to a survey of unsolved questions and possible "vistas" of future research. The actual mean length turned out to be 4,780 words, ranging from 360 to 28,000 words. The average delay in submitting manuscripts was 175 days; the mean epoch of final revision was 1954.5, and the epoch of arrival at your reviewer's desk was 1956.01. Let these numbers serve as a warning to future would-be editors! Two hundred fifteen authors whose ages range from 24 to 91 and who are from 26 countries have produced the 192 contributions for the two volumes; truly an outstanding example of international co-operation. Unfortunately, only four of the contributors are Russian.

The papers are all in English. This is especially valuable in those instances where for the first time English summaries are presented of the work of distinguished foreign astronomers and observatories. The range of topics that make their appearance varies all the way from the occurrence of gnats and mosquitoes in Sweden to the variability of the human gestation period—the latter point of critical importance in the scientific discussion!

Because of their review nature, perhaps two thirds or more of the papers would be out of place in a periodical such as the *Astrophysical Journal.* Nor would they be any more appropriately placed in a manual such as the new 5-volume *Handbuch der Astrophysik* scheduled to be published in Germany in 1957, or in Kuiper's 9-volume *Compendium of Astronomy and Astrophysics: Stars and Stellar Systems,* papers for which are tentatively scheduled for submission to the editors in 1957, 1958, and 1959. The review nature of the *Vistas* papers makes them especially useful to university teachers at all levels, and a rather large proportion of them should be considered "required reading" by such teachers. The teacher who learned his astronomy out of *Russell, Dugan and Stewart* will find this book an excellent way of deepening, extending, and bringing up to date his general background of astronomical knowledge. The same remarks apply with equal force to the graduate student in astronomy and to the active researcher. As an example, I think it important to both astronomy professor and graduate student to know the reasons for Sadler's conclusion: "After being in a state of suspended progress for many years, celestial mechanics thus is faced simultaneously with new problems and with the mechanical means of solving them."

It is obviously impossible to review all the papers here, so that any detailed remarks must be rather hit or miss. Many of the papers will be *the* standard reference source in their respective fields for years to come. An example would be Strassl's "Nomograms in Astronomy," with its excellent and detailed bibliography. Some topics are covered by two or more papers; the value of this type of approach is illustrated by three papers on photoelectric photometry by Fellgett, Huffer, and Hardie, respectively, which present a study in contrasting points of view.

Some of the papers are so concise that they need to be read and reread with great care. An example would be Bowen's paper on astronomical spectrographs, which covers the fundamental design theory and suggests novel instrumental solutions. This paper should be studied in detail by every observatory director or astronomer or engineer who has anything to do with the design or effective spectroscopic operation of a large reflector. Most of the papers in this volume, however, have little if anything to do with the work of great reflectors and, in a sense, this book is the perfect refutation to those who believe that research with large reflectors is the end-all of modern astronomy.

In the first paper by Minnaert, on international co-operation, one can hardly quarrel with his conclusion that international meetings and exchanges should be encouraged. My own feeling is that it is most important that an astronomer

work—rather than just visit—at a foreign observatory. Opportunities for an American astronomer to work in Europe or at an observatory in a British Commonwealth country are all too few, however. The Fulbright program, in theory, provides the perfect means, but to my knowledge no American astronomer has ever worked at Cambridge or Oxford or in South Africa under Fulbright auspices. Here is an opportunity for more effective action by Professor Stratton's own Commission 38 of the International Astronomical Union.

One can take issue, however, with another of Minnaert's conclusions, namely, that an auxiliary international language—such as Esperanto—would be highly desirable. Some astronomers would argue that what we need in science are fewer, not more, languages, and the fewer the better! J. E. Holmstrom has estimated that about 50 per cent of all scientific papers are published in English, 15 per cent each in French and German, and perhaps 10 per cent in Russian, with all other languages contributing the final 10 per cent. From a practical point of view, it is just too much to expect every graduate student in the sciences to be *completely fluent* in as many as three languages other than his own, or even in two. If Holmstrom's figures are even roughly correct, English is obviously a must for *all* scientists. The Dutch astronomers, for example, publish in English, and it could well be argued from a number of points of view that this fact is not completely unrelated to the very high opinion of their work that is held by non-Dutch astronomers.

Perhaps one of the most interesting papers in the volume is that by Bondi on the relative trustworthiness of "observational" and "theoretical" papers. Bondi has compiled an impressive list of observations that have later turned out to be quite inaccurate and which have led the theorists far astray. Whether or not we agree with Bondi's conclusion that theoretical results are probably of the greater reliability, we must concede that this is a perfectly natural conclusion on the part of a theoretical cosmologist. They, of all theorists, have been the most consistently and extensively betrayed by the observations. Decisive observations should be duplicated and *independently* confirmed, especially in the field of cosmology, where the importance of the observation so often is correlated with the difficulty of making it correctly. The 200-inch telescope is so much more powerful than the next largest (the 120-inch Lick reflector), that a completely independent check of its observations at the faintest and marginal end of things is impossible at present. The case for another 200-inch is clear.

Perhaps the highest praise I can give this book is that it is more than worth the price. Dr. Beer has done a magnificent job in seeing this different sort of book through to publication; it should have a profound effect on our science.

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AMATEUR TELESCOPE MAKING BOOK ONE

Albert G. Ingalls, editor. Scientific American, Inc., New York, 1955. 497 pages. $5.00.

IN ITS TWELFTH printing, this is substantially the same book as it was in the fourth edition, eleventh printing. The same basic material is found here that has assisted the beginner in making a reflecting telescope since the first edition in 1926, with the improved and advanced chapters that have been added over the years.

As every possessor of the book has found, he has to dig out much of the meaty material in the miscellany by careful reading, but for an extensive elementary treatise on the subject of telescope making, this book is still the bible of the amateur.

There are two important changes in this new printing, and the remainder of this review will concern their impact on the hobby of telescope making. First is the added footnote on page 261 of Franklin B. Wright's article on accuracy of parabolizing; the footnote is to the effect that the tolerances as published and used by amateurs over the years are too exacting by a factor of two. There is further discussion of the matter on pages 489, 490, and 491, strangely included at the end of a new chapter on the beginner's first telescope. This chapter takes the place of a section on books for the amateur, and is written by James L. Russell, a well-known Cleveland amateur telescope maker.

In the classic example of a 6-inch mirror of 48 inches focal length, the tolerance is now established at twice 44 per cent, that is, the knife-edge reading may range between 12 and 188 per cent of the calculated value. With a focal length of a little over 50 inches, the new figure is exactly 100 per cent, and in theory the mirror could therefore be left spherical, but at the outside limit of tolerance for a quarter of a wave length of light. This has been suspected by many amateurs by actual observing with mirrors that were placed in use even though they were outside the recommended tolerances of the old printings of *Amateur Telescope Making*.

Alan E. Gee is quoted as saying that more 6-inch f/8 mirrors "are worsened by attempted parabolization than are improved," and Wright states that he made his limits twice as strict as necessary to take care of imperfect measurements or imperfect focusing. On the basis of these

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statements, together with the fact that more and more persons are making telescopes just to observe the moon and other easy objects, "Unk" Ingalls has permitted the inclusion of the new chapter on the beginner's first telescope. But he is careful to bring out the fact that precision twice that of the Rayleigh limit may not be sufficient for the exacting and experienced planetary observer, and he quotes Dr. James G. Baker to the effect that for very low contrast levels and faint planetary details it may be necessary to have an optical system perfect to 1/50 wave length of light.

Extreme simplification of material and instructions is the theme of the new beginner's chapter. Plate glass is used to replace pyrex for faster grinding; the mirror is to be left spherical (or at whatever figure it attains lacking any testing whatsoever) at around 50 inches focal length to eliminate parabolizing; and a simple pipe stand (altazimuth) and open stick make up the mounting. As Editor Ingalls points out, "the method of mirror making described in the chapter has been cut to the bone."

This material will cause much lively comment among the fraternity of established telescope makers. It is sure to bring up the old question of who constitutes a telescope maker. Is it one who makes a good mirror and mounting with which to look at the heavens, or is it also the person who purchases a ready-made mirror or telescope kit and assembles it to make his instrument?

It is generally conceded that anyone who mounts a mirror or lens as a telescope for viewing celestial objects has become a telescope "nut" regardless of how the optics were obtained. There is only one important requirement—that the optics be of first quality, capable of giving satisfactory views of the moon, the sun, double stars, clusters, nebulae, and the planets. The author of this simplified approach to the beginner's first telescope has cut so many corners in his instructions that in the opinion of many amateurs and the present reviewer such an instrument will not fall into the classification given above.

A general accumulation of stretched optical tolerances should prevent the average instrument made with Mr. Russell's advice from performing as well as the inexpensive, machine-produced long-focus mirrors in kits now available from various telescope supply houses. If someone attends a class in telescope making, he should expect, at least, to produce a mirror and telescope of some quality, yet these same instructions are given to class members at the Cleveland Museum of Natural History (but there no doubt the instructors themselves fill in the gaps, and a test of sorts *is* used). The editor points out very carefully that this is to be a "pilot" instrument, and that the experience gained will permit construction of a far more satisfactory second telescope, better than the tyro might have achieved in the first place were he to try to meet the requirements of parabolizing, Foucault testing, and the like. Therefore, let us look at Mr. Russell's method and see what recommendations might be included in the next printing to make the finished pilot telescope reasonably useful.

Leaving the mirror untested and hoping it is spherical may be all right at a focal length of 50 inches, in view of Mr. Wright's relaxed tolerances, but to stretch the limit as far as the statement on page 482 is going too far: "No special harm will result—don't throw the mirror away—if this measurement proves to be 36 inches or even 60 inches." At 36 inches even the new tolerance is 36 per cent, a stringent limitation.

The reviewer has had actual experience with a similar tolerance limit when he used a 6-inch mirror of 43 inches focus while it was spherical and later after it had been 85-per-cent parabolized. When spherical, the mirror had difficulty splitting the double star Castor, but after correction it was easily separated. It is advisable to let the focal length be on the long side of 50 inches, but not on the short side, because of the tolerance limit. Back in the early '30's, telescope mirrors made at the American Museum of Natural History under Ramiro Que'sada were left spherical at focal lengths of 60 to 72 inches. In the New York atmosphere they performed as well as the figured f/8 mirrors made by other amateurs in the vicinity.

The use of honeycomb foundation (HCF) as a polishing material does give a fast shine, but results in an optically rough or lemon-peel finish. This surface contributes slightly to the deterioration of the image. Instead, it would be better to polish a quick shine with HCF, and to finish off with a pitch lap for good optical smoothing. Mr. Russell seems to feel strongly that pitch laps are the bane of the beginner, but other instructors have expressed the view that HCF is a very difficult material, that contact is impossible to maintain, and that the results are poor. At present, there are few proponents of honeycomb foundation for final polishing, and no one would use it for figuring a quality mirror.

The most amazing part of these instructions is that the finished mirror is not tested for figure by any of the standard methods, just assumed to be spherical by watching the polish come on the glass in a fairly regular manner. Thousands upon thousands of optical workers, amateur and professional, have wished since the discovery of glassworking that things would go so easily. It is as difficult to produce a good sphere, with regular testing, as to procure a good parabolic curve. This is particularly true of the relatively flat curve of the amateur's average mirror. And workers who have tried to make

deep Schmidt primaries and expected to have them polish spherical have found a great deal of work at figuring the final surface was necessary.

On page 479, Mr. Russell points out that unless the edge polishes soon after the center, it may be necessary to go back and regrind a more nearly spherical curve on the mirror. His suggestion that a new lap be tried to bring a stubborn edge to polish may work without a return to grinding, but experienced mirror makers will shudder to think of the edge zone that forcing the polish in this manner can produce.

This reviewer cannot comprehend why a simple test is not used or recommended. Even a one-wire Ronchi test should be understood by the least-informed novice, yet serve to keep the mirror smooth and to catch any "wild" figures that would otherwise escape notice. Actually, all the thrill of making a mirror is in the figuring—the other steps are mostly mechanical, leading up to this final stage. If one doesn't figure his mirror, even for a spherical surface, he might be better off to purchase a ready-made long-focus spherical mirror and mount that. Then the desire for a better instrument will lead him to make a figured mirror with his own hands as have tens of thousands before him.

It appears to me that the weakness of this chapter is in assuming that the ability of amateurs is so limited. The neophyte needs confidence that he can produce a good telescope, not just a passable one. Even if it takes more time, and if classes in sound telescope making practices have to be restricted in size, the result on the part of both instructor and pupil is worth the time spent.

The use of plate glass for the diagonal is unfortunate. Water-white glass or crystallex would be better; both of these have a smoother surface and more regular figure than plate glass. The latter is not only far from flat, but its surface is liable to be astigmatic. Only selected plate should be used, carefully tested for astigmatism and rejected for any trace of it. For only a little more money, the amateur can purchase an inexpensive prism from the same commercial producer who supplies his eyepiece. War-surplus prisms are of generally satisfactory quality for such a telescope, provided they are not cut from tank prisms. It is well to state to the supplier that the prism will be used astronomically.

Amateur Telescope Making—Book One remains as excellent as ever, but before recommending the new printing to beginners one should advise them of the pitfalls that lurk in Part XII. Fortunately, material from other sections of the book can be substituted where one does not wish to follow these simple new instructions.

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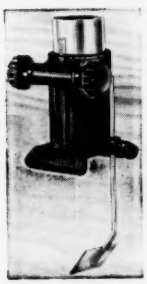

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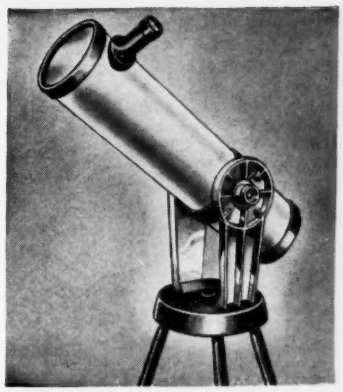

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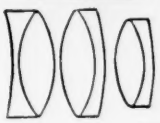

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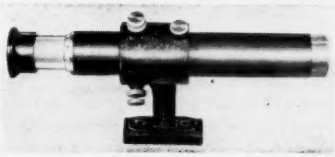

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NOTES ON BASIC OPTICS — XIX

8. Reflecting Telescopes

1. **Image Formation by Mirrors.** As we have already seen, mirrors as well as lenses can form images. A concave spherical mirror converges light, thus having positive power, and is equivalent to a positive lens. Conversely, a convex mirror is equivalent to a negative lens.

Mirrors obey the same laws of image formation as lenses, except that each mirror in an optical system turns the path of the light through 180 degrees. In dealing with light rays in a reflecting system, the same equations can be used as for lenses, provided that the ratio of refractive indexes at the mirror surface is assumed to be −1. This substitution also takes care of the reversal of direction of the light.

Furthermore, mirrors exhibit some of the same aberrations as lenses. A concave spherical mirror is represented in Fig. 56a, where rays from an infinitely distant object proceed parallel to the optical axis, meeting the mirror surface at various angles of incidence. Since the angle of reflection is equal to the angle of incidence, we can plot the reflected rays and find where each one intersects the optical axis. Clearly, the spherical mirror exhibits spherical aberration like that caused by a positive refracting surface.

A concave mirror will have no spherical aberration for an axial point if the surface is a paraboloid of revolution, as in Fig. 56b. This is the reason we use paraboloidal mirrors in many telescopes; it is not too difficult to manufacture such a surface. But the form of refracting surface—an **aplanatic** one—that gives zero spherical aberration for an axial point is very hard to make.

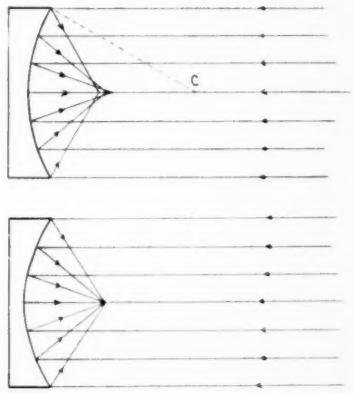

Fig. 56. Part "a" shows the spherical aberration caused by a spherical reflecting surface. This is corrected for axial rays by making the surface a paraboloid, as drawn in part "b."

2. **Some Properties of Reflecting Systems.** There is one serious difficulty in reflecting optical systems: Since the light is turned through 180 degrees, any subsequent component such as an eyepiece or second mirror obstructs the entering light beam. This usually restricts reflecting systems to relatively small fields of view (with the image of the field of view considerably smaller than the entrance pupil), and it virtually rules out systems containing more than two or three image-forming mirrors. Nevertheless, reflecting optical systems are frequently used because they have several important advantages.

The greatest advantage is that reflecting systems of large relative aperture are easily made. The fastest refracting system theoretically possible is f/0.5, and those faster than f/1.0 are unusual and generally contain many elements. However, f/1.0 parabolic mirrors are readily made by skilled opticians, and some f/0.25 paraboloids are in use.

A second advantage is that reflecting systems are free from chromatic aberration, since the angle of reflection does not depend on the wave length of light. Thus, a single paraboloidal reflecting surface is perfectly corrected for an axial image point. On the other hand, in re-

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fracting systems at least three surfaces are required to give even approximate correction for spherical aberration, and chromatic aberration can be only partly eliminated.

A single paraboloidal surface is much cheaper to produce than the four refracting surfaces of an achromatic doublet. Also, the mirror need not be made of expensive optical glass. As the size of the optical system increases, these economic advantages become even more important; this is a major reason why large astronomical telescopes are nearly all reflectors.

3. **Correction of Reflecting Systems.** The design of a reflecting system differs from that of a refracting system, because of the unavoidable obstruction of light, which limits the number of reflecting surfaces that can be used. The designer of a refracting system may introduce as many surfaces and different kinds of glass as are needed to get the necessary degree of correction; the limit to the number of elements is set only by cost, and by the need of transmitting enough light. For reflecting systems, the limitations are much more serious; as we have seen, use of more than two or three curved reflecting surfaces is not feasible.

Therefore, the designer of a reflecting system has a choice of two or three forms of mirror surfaces, whose aberrational properties are useful (or harmless) for the purpose intended. For example, in the Cassegrainian telescope (to be discussed later), a pair of reflecting surfaces gives theoretically perfect axial imagery, but relatively poor correction for the off-axis aberrations. This is adequate for the purpose, since Cassegrainian fields of view are usually small. In general, reflecting systems are better corrected for specific aberrations, and refracting systems have much better over-all corrections.

4. **The Newtonian Telescope.** The commonest form of reflector for visual use is the Newtonian, named for Sir Isaac Newton, who introduced it. It consists of a paraboloidal mirror with a suitable deflecting mirror or prism near the focal plane to bring the image outside the light beam where an eyepiece or photographic plate may be placed. The diagonal's position is shown in Fig. 57.

Because of the simplicity of its single image-forming surface, the Newtonian is usually the first instrument attempted by an amateur telescope maker. A person reasonably competent in manual arts can make a 6-inch or 8-inch mirror quite handily, figuring the surface to a paraboloid. Fabrication of an achromatic lens of equal size is a considerable task, even for an experienced optician.

A paraboloidal mirror is perfectly corrected for an axial image point, but its off-axis aberrations, especially coma, are quite severe. Therefore, the pure Newtonian form is not usable over more than a field of one or two degrees, depending on the focal ratio. For longer focal lengths at a given aperture, the field of view is larger. At the f-numbers ordinarily used by amateurs, f/6 or greater, the restriction of the field by aberrations is not particularly objectionable—with a field of view greater than two or three degrees the diagonal would obstruct too much light anyway. In the larger instruments of observatories, where the f-number is small (f/3.3 for the 200-inch Hale reflector), correction lenses are inserted near the focal plane to compensate for the coma of the paraboloid and to extend the useful field.

5. **Off-axis Mirrors.** If the obstruction of the entering beam of light by the secondary mirror is considered serious, recourse may be had to an off-axis system (Fig. 58), at the cost of considerably more

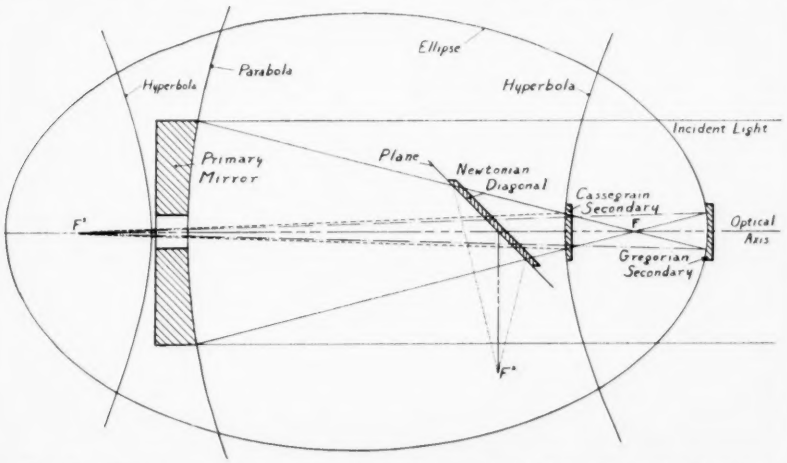

Fig. 57. The same primary mirror is used in each of three types of reflector in this diagram. F is the focus of the primary mirror, and of the parabola. The focus of the Newtonian form is at F^2, and that for both the Cassegrainian and the Gregorian is at F^1. F and F^1 are the two foci of the ellipse, as well as the conjugate foci of the secondary mirrors. (In some Cassegrainians, the primary mirror is unperforated, and a flat mirror just in front of it diverts the focus F^1 to the side.) The Cassegrainian secondary is on one branch of a hyperbola.

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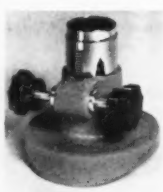

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effort in construction. In this case, the primary mirror is a section of a much larger imaginary mirror along whose axis the image is formed. Manufacture of an off-axis paraboloidal mirror is clearly not a task for a neophyte.

It must be remembered that the aberrations of an off-axis mirror are always much worse than those of a centered system, because these aberrations are associated with the aperture of the fictitious mirror. There is moreover a lack of symmetry in the image patch that may further affect its quality.

At long focal ratios, such as f/10 or greater for a 6-inch mirror, the difference between sphere and paraboloid is so small that the Newtonian primary may be left spherical. Such a spherical mirror may be used off-axis without special fabrication problems, but the above warnings as to the aberrations still hold.

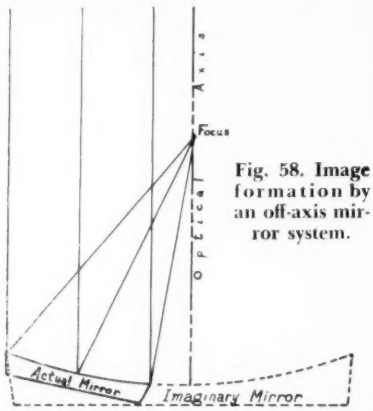


Fig. 58. Image formation by an off-axis mirror system.

6. **Two-mirror Systems.** Let us suppose we have a reflecting surface *of any shape whatever*. Theoretically, it is possible to find another reflecting surface which, placed in the path of a given bundle of light rays reflected from the first surface, will bring all the rays of the bundle to a perfect focus. In this sense, there are an infinite number of two-mirror systems that will image an axial point without aberration.

In order to form a useful optical system, however, we must consider the aberrations for off-axis points, since we are not usually interested in a field of view of zero diameter. The restriction to systems that have some useful field of view eliminates most of the possible forms, and others are ruled out because their surfaces are too difficult to make. Thus, there are relatively few practical two-mirror systems. Yet, it is always possible that some entirely new useful combination of mirror surfaces may be discovered.

The five best-known two-mirror telescope combinations are the Cassegrainian, the Gregorian, the Dall-Kirkham, the Ritchey-Chrétien, and the Schwarzschild. Only the first of these is in wide general use, because the primary mirror of the Cassegrainian is a paraboloid, just as in the Newtonian.

Most of the larger astronomical reflectors, such as the 100-inch and 200-inch instruments of Mount Wilson and Palomar Observatories, are constructed with paraboloidal primary mirrors. Each has several interchangeable Cassegrainian secondaries, so that various equivalent focal lengths may be used, giving the observer a wide choice of image sizes.

The Cassegrainian secondary is placed in the converging cone from the primary, and the surface of the secondary is a portion of a hyperboloid of revolution. This convex surface reflects the converging cone to a secondary focus without spherical aberration. Fig. 57 shows that the Cassegrainian secondary is placed on one branch of the hyperbola. The primary and secondary foci are the two foci of the hyperbola. The vertex radius of the required hyperboloid can be determined by the paraxial lens equations.

This form of two-mirror system is exactly equivalent to a telephoto lens, consisting of a positive and a negative component with a finite separation. The same equations hold as for the telephoto lens, given in November, 1953.

If the secondary mirror is concave, it is placed beyond the primary focus, and the telescope becomes a Gregorian. In this case, the required surface is an ellipsoid, with the primary and secondary foci located at the foci of the ellipse, as also shown in Fig. 57.

The Gregorian telescope is equivalent to a positive lens followed by an erecting system. The image is erect, in contrast to the inverted image of the Newtonian and the Cassegrainian. But the Gregorian telescope is not often found today; its main disadvantage from the design viewpoint is a strongly curved field.

In cases where interchangeable secondaries are not required, and where the primary need not perform as a Newtonian, other two-mirror systems may be used with certain advantages. The Dall-Kirkham is one of these, a form of Cassegrainian that is much easier to manufacture, particularly for amateur telescope makers.

Instead of having a hyperboloidal shape, the surface of the Dall-Kirkham secondary is spherical, and the primary is given the figure necessary to correct the spherical aberration of the secondary mirror. Here we avoid the difficulty of testing the convex nonspherical secondary of the true Cassegrainian. If we are to finish a surface to a shape other than spherical, and test it adequately, this can be done much more easily for a concave than for a convex surface.

The actual shape of the concave primary in the Dall-Kirkham system is what opticians call an undercorrected paraboloid. It is not a conic section at all, and it is not formed by duplicating a theoretical surface. The mirror is tested in combination with its secondary, and is worked until the axial imagery is brought to the required degree of perfection.

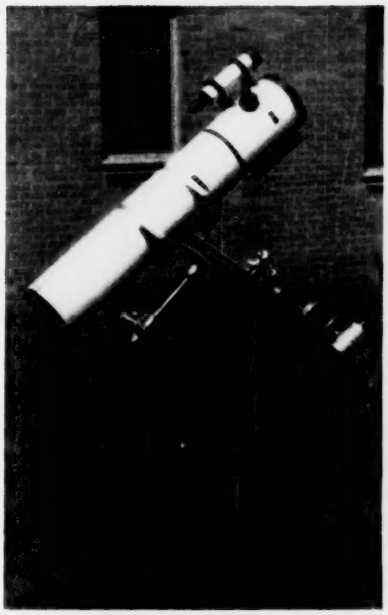
The Ritchey-Chrétien telescope is chiefly of interest because the U. S. Naval Observatory has a 40-inch reflector of this form. It is essentially a Cassegrainian, but with both mirrors aspherical. The Schwarzschild has a concave secondary mirror placed inside the primary focus, thereby reducing the equivalent focal length of the combination and producing the final image between the two mirrors. Both the Ritchey-Chrétien and the Schwarzschild are aplanatic systems, theoretically free of spherical aberration and coma, but they have other disadvantages that make them of little interest to most astronomers.

(To be continued)

INEXPENSIVE SETTING CIRCLES AND SLOW MOTIONS

MANY AMATEURS steer away from setting circles and slow-motion controls because of the expense of fancy metal-working equipment or the cost of having parts machined outside. I have equipped my 6-inch Newtonian reflector with both of these conveniences at a minimum of cost and without special tools.

For the setting circles a clear plastic Dietzgen 6" protractor was purchased. I laid the protractor, as if it were a negative, on a piece of photographic paper, exposed the paper by turning on the room light, and then developed it. The resulting print has white markings evenly spaced on a black background, ideal for nighttime use. The print was glued to a $6\frac{1}{4}$" disk of $\frac{1}{4}$" plywood. The numbers for every 10 degrees were typed on a sheet of paper, then punched out and glued to the disk. A coat of varnish weatherproofed the unit.



The Gordon Hall 6-inch telescope.

The right-ascension circle can be ro-

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Size	*Thickness*	*Price*
$4\frac{1}{4}$"	$\frac{3}{4}$"	$ 5.50
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8"	$1\frac{1}{2}$"	$17.00
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$6\frac{1}{2}$" dia. x $\frac{1}{8}$" thick—$\frac{1}{4}$" dia. center hole.

High grade optical glass free of striae. Precision workmanship throughout. Optically polished. Free of transmission defects. Satisfaction guaranteed.

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We are now offering a new Richest Field ASTROLA, unmounted, 24" focal length, 6-inch mirror, with 28-mm. ocular. The tube is 26 inches long and the telescope may be cradled in the arms. **$125.00**

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6" ..... **$ 60.00**
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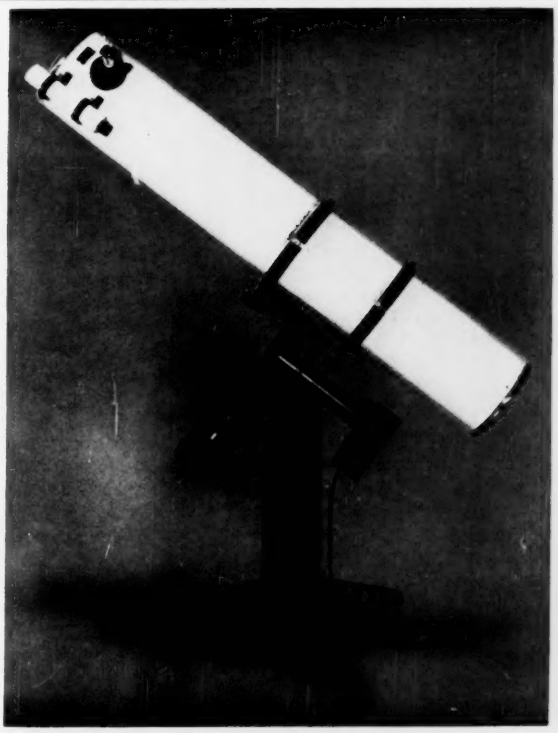

The above is the new De Luxe Model "B", 8-inch, with electric clock drive, setting circles, and rotating tube **$575.00**

For the discriminating amateur and the discerning professional.

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3/4"	$3.75
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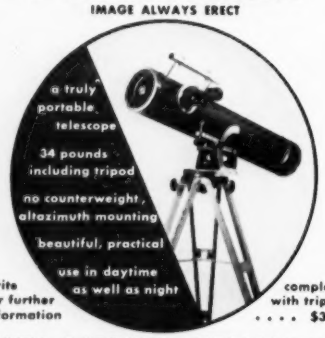
a truly portable telescope
34 pounds including tripod
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beautiful, practical
use in daytime as well as night
write for further information
complete with tripod $395

SANTA BARBARA TELESCOPE CO.

607 MIRAMONTE DR., SANTA BARBARA, CALIF.

tated to set it at the proper sidereal time. The right-ascension circle is held by a piece of eyepiece tubing, which acts as a bearing, and this is kept in place with a washer. A strip of sandpaper glued around the outer edge of the plywood disk makes a nice grip.

The slow-motion controls are made of Reynolds do-it-yourself aluminum and two aluminum pulleys. The worm is a piece of 3/8" rod about 4" long with 16 threads per inch. The shaft extenders, couplings, and flexible shafts were obtained from Allied Radio Corp. The worm bracket is made of aluminum pieces bolted together, but other mountings might require different brackets.

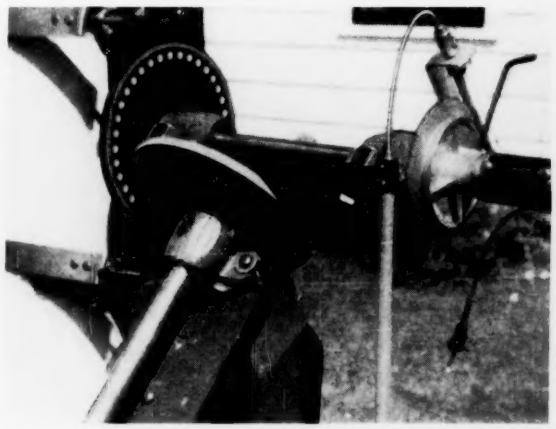
The worm gears were made from 4" aluminum pulleys. I put each pulley on the shaft of an electric motor and ground one lip off with a coarse file. Then I placed a steel bolt having the same thread as the worm against the remaining lip of the pulley and tapped the bolt lightly with a hammer. This made marks 1/16" apart on the edge of the pulley. Using the marks as a guide, I cut teeth 1/16" deep all around the lip with a hack saw.

Once more I put the bolt against the lip and pounded it hard with the hammer, which process formed the teeth on the pulley to the correct shape. The teeth did not come out even at the end; consequently, there is a small gap in each gear, but the worm goes over this smoothly. The 4" pulleys each have 200 teeth, giving a ratio of 200 to 1. Smaller pulleys would have less teeth and a correspondingly lower ratio. It took a little over two hours to make each worm gear.

The setscrew on each pulley acts as a clutch. I have glued an Allen wrench in the setscrew to make it easier to use, and the wrench can't get mislaid.

My telescope is on a portable mounting and therefore is not perfectly aligned with the earth's axis. Consequently, when the setting circles are used to locate an object, it is seldom placed in the field of view exactly. It is so close, however, that it can be picked up in a moment with a low-power eyepiece. This is quicker and much less discouraging than sweeping the sky.

The slow-motion controls are actuated by cables that may be easily retained in the observer's hands regardless of the position of the telescope. These cables hang downward when not in use, as seen in the photograph of the entire instrument. They are, of course, very convenient, and work smoothly enough to permit me to take photographs of long exposure with a short-focus camera attached to the telescope.



The homemade setting circles of Mr. Hall's telescope are of ample size and easy to read under observing conditions.

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- Rugged steel construction.
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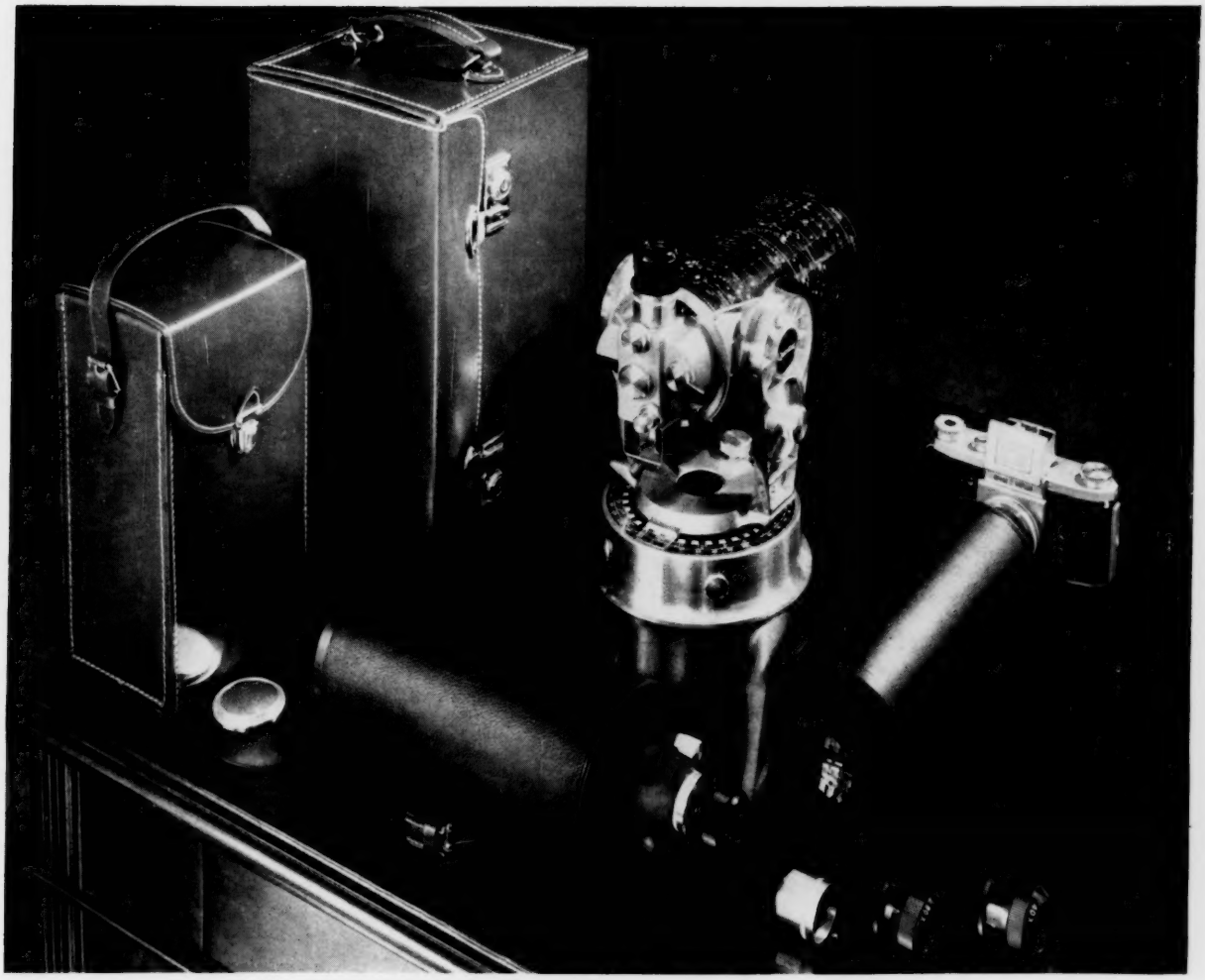

Announcing the QUESTAR FIELD MODEL

The new Field Model is a featherweight version of Questar without the elegant full polar-equatorial mounting. It is priced at only $495. It weighs less than a 7 x 50 binocular and makes the famous Questar optical system available for use with any camera tripod and all standard eyepieces.

The Field Model was developed at the request of government agencies and camera enthusiasts to do a wide range of high-power telescopic photography, in which Questar has outperformed competitive products of much greater size and cost.

But this is not just a telephoto lens — it is the standard Questar, the most versatile telescope in the world. Focusing to eight feet, it is also a long-distance microscope, and the same Questar sun filter that has been setting new records in solar work may be used for sharper, safer views of the great sunspots which have been so active recently. Both Questar models are identical but for their mountings, both are well and truly made and tested.

The square nameplate on the Field Model reads "Questar Catadioptric Photo-Visual Telescope F:12.1 AP 89 mm. FL 1077 mm." So sharp a 42.4" lens is in itself a challenge to the 35-mm. photographer. How much of what Questar shows so clearly will he be able to capture on his negative? Achieving theoretical perfection of image for its 3½" aperture, this instrument furthermore brings all colors, including the infrared, to the same focal point.

For the amateur, this 31-ounce telescope represents the utmost in convenience and versatility. He may mount it to suit his fancy for the host of astronomical uses at which it excels. With the amateur's needs in mind we have bored the bracket casting cylindrically to take any standard 1¼" diameter ocular or accessory. This means that your own battery of favorite eyepieces, Barlows, prisms and auxiliary equipment may be used, at any power you choose. And a large nylon tangent screw may be tightened with a coin to clamp each accessory firmly without danger of surface scratches.

The bracket itself is of high-strength heat-treated aluminum alloy, black anodized after machining. Its 2" x 2" base is tapped for both foreign and domestic tripod screws.

The barrel of the Field Model Questar is covered in genuine Morocco leather at the studios of Albert Oldach & Son of Philadelphia, binders of fine books since 1875. The handsome velvet-lined leather case is included in the purchase price and is handmade in England, of the same materials its makers use for the case of the De Luxe Questar. An extension strap provides for shoulder carrying when desired. Instrument and case together weigh less than 3 pounds. Never before has there been so much fine telescope in so small a package.

Questar Field Model in case, $495, your check for $100 will reserve an instrument; Questar 40x Eyepiece, $20; Questar Wide-Field Erfle 80x Eyepiece, $25; Questar Eyepiece Adapter Tube, $6.00 (only one required); Questar Sun Filter, $25; De Luxe Questar with all accessories, $995, reservation $300. All are shipped insured and prepaid in the continental United States.

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40 power

NEW! JUST OFF THE ASSEMBLY LINE!

Never before has anything like this been offered at so low a price. Here is another example of American ingenuity. Big 3" diameter achromatic coated objective which will give needle-sharp crystal-clear images. Focusing is a delight with the micrometer spiral focusing drawtube. Light-weight aluminum construction throughout, black crackle finish. length open 22 inches, closed 17 inches. This telescope gives an upright image — it is WONDERFUL for astronomy, SUPERB for long distances, EXCELLENT as a spotting scope.

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Aluminum Telescope Tubing

O.D.	I.D.	Price Per Ft.
2¼"	2⅛"	$1.20
3⅜"	3¼"	1.75
4½"	4⅜"	2.75
5"	4⅞"	2.75

All tubing is shipped POSTPAID

Focusing Eyepiece Mounts Rack & Pinion Type

The aluminum body casting is finished in black crackle paint and is machined to fit all our aluminum tubing. Has a chrome-plated brass focusing tube, which accommodates standard 1¼" eyepieces.

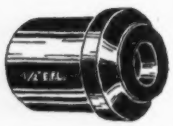
For 2⅛" I.D. Tubing	Postpaid	$12.95
For 3¼" I.D. Tubing	"	12.95
For 4⅜" I.D. Tubing	"	12.95

Reflector type for all size tubing.
Complete with diagonal holder.....$ 9.95

Aluminum Lens Cells Black Anodized

Cell for Lenses	Cell Fits Tubing	Price
54 mm Diam.	2⅛" I.D.	$ 3.50
78 mm "	3¼" "	6.50
81 mm "	3¼" "	6.50
83 mm "	3¼" "	6.50
110 mm "	4⅜" "	10.50

MOUNTED EYEPIECES



Each of these eyepieces is the buy of a lifetime at a terrific saving to you. Perfect war-surplus lenses set in black anodized standard aluminum 1¼" O.D. mounts.

F.L.	TYPE	PRICE
12.5 mm (½")	Symmetrical.....	$ 6.00
16 mm (⅝")	Erfle (wide angle)...	12.50
16 mm (⅝")	Triplet.....	12.50
18 mm (¾")	Symmetrical.....	6.00
22 mm (27/32")	Kellner.....	6.00
32 mm (1¼")	Orthoscopic.....	12.50
35 mm (1⅜")	Symmetrical.....	8.00
55 mm (2⅛")	Kellner.....	6.00

The above eyepieces can be supplied **COATED** at 75 cents each extra.

AN ECONOMICAL EYEPIECE

This mounted eyepiece has two perfect fluoride-coated lenses 29 mm in diameter. It is designed to give good eye relief. It has an effective focal length of 1¼" (8x). The eyepiece cell fits a 1¼" tube..... **$4.50**

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Known among amateurs as the "Giant Jaegers," this is the finest wide-angle eyepiece ever made. It gives a flat field. It is mounted in a focusing cell. This is an Erfle eyepiece, 1½" effective focal length, with a clear aperture of 2 3/16". It may be used as a Kodachrome viewer, magnifying seven times.

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BRAND NEW COATED 1¼" E.F.L. wide angle eyepiece. Contains 3 perfect achromats. Aperture is 1 3/16". (Illustrated) **$12.50**

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7. 48" or 62" FOCAL LENGTH
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9. Lowest Price
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Each lens is thoroughly tested by us and is guaranteed to resolve two seconds of arc or better. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cell is machined to close tolerances so that it will fit directly over our standard aluminum tubing, eliminating any mounting problems.

3¼" diam., 48" f.l. (uncoated).. **$28.00** 4⅛" diam., 62" f.l. (uncoated).. **$60.00**
Same as above with coating.... **$32.00** Same as above with coating.... **$69.00**

We can supply ALUMINUM TUBING for the above lenses.

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We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

Diameter	Focal Length	Each	Diameter	Focal Length	Each
54 mm (2⅛")	254 mm (10")	$12.50	83 mm (3¼")	660 mm (26")	$28.00
54 mm (2⅛")	300 mm (11.8")	12.50	83 mm (3¼")	711 mm (28")	28.00
54 mm (2⅛")	330 mm (13")	12.50	83 mm (3¼")	762 mm (30")	28.00
54 mm (2⅛")	390 mm (15.4")	9.75	83 mm (3¼")	876 mm (34½") ...	28.00
54 mm (2⅛")	508 mm (20")	12.50	83 mm (3¼")	1016 mm (40")	30.00
54 mm (2⅛")	600 mm (23½") ...	12.50	102 mm (4")	876 mm (34½") ...	60.00
54 mm (2⅛")	762 mm (30")	12.50	108 mm (4¼")	914 mm (36")	60.00
54 mm (2⅛")	1016 mm (40")	12.50	110 mm (4⅜")*	1069 mm (42 1/16")	60.00
78 mm (3 1/16")	381 mm (15")	21.00	110 mm (4⅜")	1069 mm (42 1/16")	67.00
80 mm (3⅛")	495 mm (19½") ...	28.00	128 mm (5 1/16")*	628 mm (24¾") ...	75.00
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*Not coated

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

February Sunspots and a Red Aurora

SOLAR ACTIVITY reached a new high during February, when the largest sunspot group in the current cycle was seen, a very strong solar flare occurred, and prominence activity was great. The flare was detected at Kodaikanal, India, and at Tokyo, 3:30 UT, February 23rd. It was followed at 3:45 by the start of the greatest burst of cosmic ray intensity ever recorded, and by radio fadeouts, bright auroras, and the most intense geomagnetic storm of the present cycle (see page 291).

The follo-wing reports from two readers of *Sky and Telescope* are therefore of special interest:

The accompanying photograph of the remarkable sunspot group that reached the solar central meridian on February 17th was taken by me on the preceding day with a 4-inch refractor. For spot photography, the objective opening is reduced to one inch, and the light intensity is further cut down with two No. 4 neutral-density filters and one light yellow.

A 30-mm. projection lens gives a solar image three inches in diameter. Since mine is a 35-mm. reflex camera, only part of the sun's disk can be photographed at one time, but fairly good details of spots are recorded. The fine-grain positive film has a Weston speed of 4, exposure time about 1/100 second. One advantage in this type of film is control of the development in the darkroom under red light until the desired density is achieved.

I barely missed witnessing the intense flare of February 23rd, as only 30 minutes earlier I had been observing the sun by projection.

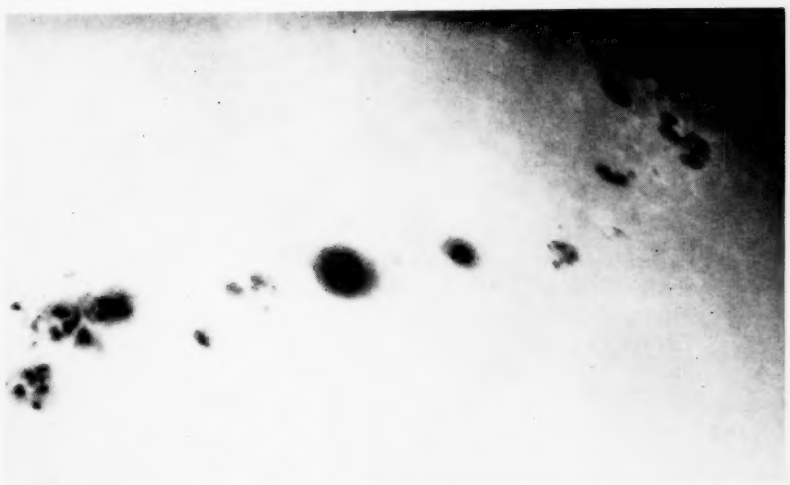
HANS ARBER
P. O. Box 125
Manila, Philippines

An unusual red auroral display was seen at College, Alaska, from 00:15 to 01:30, Alaska standard time, on the night of February 24-25, 1956. When first noticed, this aurora was a bright red patch in the southeastern sky, and its intensity was visually estimated at 4 on a 0-to-5 scale. The patch was located in the vicinity of clouds, and it was first thought to be the reflection of a large fire.

By 00:25, the red aurora had spread to the westward in an arclike form, and the lower border was 12 degrees above the southern horizon. The red arc was easily seen as high as 35 degrees and appeared to extend 40 to 45 degrees in altitude. The nearby full moon, however, prevented tracing the red arc farther north at this time. The two ends of the arc were at the effective horizon 45 degrees south of east and due west, respectively.

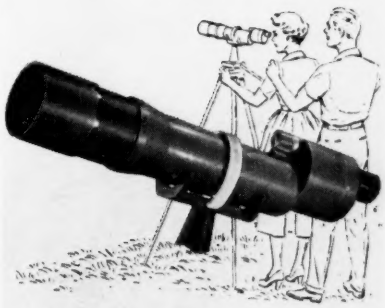
At approximately this same time a normal rayed arc formed, appearing to be superimposed upon the red one. The rayed arc quickly broke into a rayed band, moving northward and becoming more complex in appearance. By 00:35, rayed forms covered most of the sky, and red auroral glow and patches were seen in the northwest quadrant, extending from the zenith to an estimated 10 degrees above the horizon. A remnant of the southern arc was still visible at this time.

The display continued, with patches of red in the northwest as well as in the east. Again normal rayed auroral forms appeared in the vicinity of the brighter red areas. The sky clouded over at 02:00 and no observations were obtained after that time. Except at the onset of this red aurora at 00:15, the sky was more or less covered by rays, rayed arcs, and rayed bands during the entire period of obser-



This great sunspot procession was photographed by Hans Arber on February 16th, at 03:30 UT. The edge of the sun is visible in the upper right.

THE SKY IS YOURS



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BALscope Sr.
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A superb telescope, the BALscope, Sr. has more than sufficient resolving power and magnification for both instruction and personal enjoyment of amateur astronomy as a hobby. Its high light-gathering power and lack of stray light enables the user to observe stars down to the tenth magnitude on moonless nights.

You'll enjoy its excellent portability, too. So compact, you can carry it anywhere and mount it on any pan-head camera tripod with B&L tripod adapter. Focusing is simple yet precise with its unique prism-focusing system . . . even the beginner can focus with perfect accuracy. Four easily interchangeable eyepieces ranging from 15X to 60X provide excellent results—from Star Clouds to Double Stars.

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vation—normal auroral forms as seen at this latitude.

It seemed that the red aurora patches were brightest immediately to the south of the most active rayed forms, but a red glow was often seen in areas apparently free of rayed aurora. In a number of instances, a portion of the red glow brightened just before the appearance or brightening of rayed aurora in particular regions.

The maximum coverage of the red glow at any one time was at least from the zenith to 15 degrees above the northern horizon, when it was thought that a faint red patch was also visible in the south. As for over-all coverage, definite measurements were made of red aurora 12 degrees above the southern horizon and eight degrees above the northern horizon. These measurements are accurate to about half a degree.

Since the red auroral arcs are believed to occur at greater heights than normal arcs, Dr. C. T. Elvey, director of the Geophysical Institute, University of Alaska, requests anyone who observed this particular arc to send him details of its position in the sky. One quite reliable observation has already been received which indicates that the base of the red arc may have been as high as 300 kilometers.

HAROLD LEINBACH
Geophysical Institute
University of Alaska
College, Alaska

CLOSE CONJUNCTION OF NEPTUNE AND STAR OBSERVED

Predictions were given on page 240 of the March issue of a very near approach of the planet Neptune to the 7½-magnitude star BD −9° 3807 on the evening of March 9th. Several reports of amateur observations of this event have been received.

Members of the Richmond Astronomical Society in Virginia watched the phenomenon with four telescopes, ranging from a 12½-inch reflector to a 3-inch refractor. T. L. Ogburn, III, reporting for this group, described Neptune as blue in color. The general impression of these observers was that closest approach occurred about an hour before the predicted time of 11:18 p.m. EST. Watchers with the 12½-inch, who began work at 10:30, judged that the minimum clear space between planet and star had been about one second of arc, not later than 10:20.

Stephen P. Maran and George Hein, of the Junior Astronomy Club of Brooklyn, N. Y., observed with a 6-inch reflector and 115x, noting the closest approach as about 11:17 p.m., with an estimated separation of 4″ to 6″. Another member of the club, P. Skaritka, observed the combined brightness of Neptune and the star with 7 x 56 binoculars. His 15 estimates between 11:19 p.m. and 2:00 a.m. all gave 6.9 or 7.0 for the combined magnitude.

SUNSPOT NUMBERS

February 1, 50, 40; **2,** 75, 50; **3,** 69, 60; **4,** 52, 57; **5,** 35, 26; **6,** 38, 34; **7,** 37, 29; **8,** 42, 25; **9,** 40, 31; **10,** 29, 29; **11,** 47, 56; **12,** 75, 80; **13,** 96, 90; **14,** 124, 142; **15,** 121, 168; **16,** 153, 224; **17,** 175, 237; **18,** 158, 270; **19,** 212, 246; **20,** 206, 260; **21,** 168, 208; **22,** 156, 186; **23,** 152, 177; **24,** 147, 156; **25,** 140, 149; **26,** 116, 140; **27,** 113, 122; **28,** 132, 132; **29,** 128, 132. Means for February: 106.4 American; 122.6 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

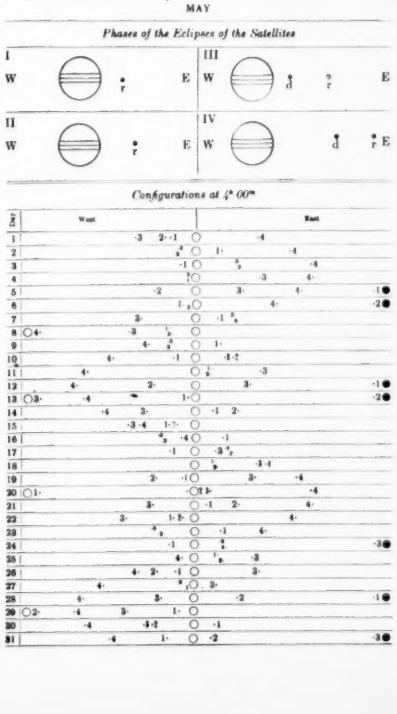
Dr. M. Waldmeier, Zurich Observatory, reports the following definitive sunspot numbers for 1955: January, 23.1; February, 20.8; March, 4.9; April, 11.3; May, 28.9; June, 31.7; July, 26.7; August, 40.7; September, 42.7; October, 58.5; November, 89.2; December, 76.9.

Predictions of the smoothed monthly sunspot numbers have been supplied by Dr. Waldmeier for the next few months: May, 116; June, 125; July, 133; and August, 140. He states that the coming sunspot maximum will be earlier and higher than his forecast on page 190 of the February issue; peak activity should occur around 1957.1, with a highest smoothed monthly sunspot number of about 170.

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

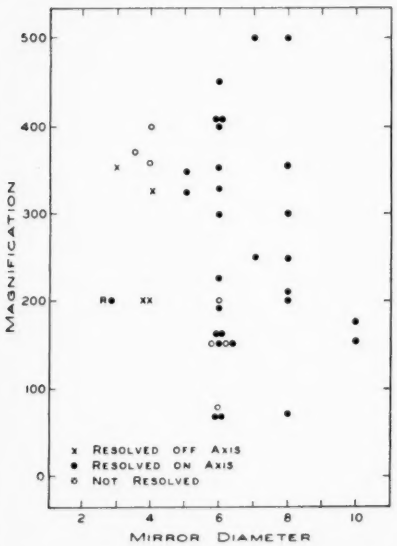
In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac*.



DEEP-SKY WONDERS

CERTAINLY no suggestion by me in this column has raised more activity than the request last September for observations of Delta and Mu Cygni with small reflectors. Over 50 amateurs responded, including a few observers with small refractors. Apparently, this was one of the first attempts at a large-scale test of the performance of homemade reflectors on double stars. In the reports, variations of atmosphere and the effects of geography were plainly evident, and the replies all showed a gratifying honesty in reporting.

The majority, but not all, of the observers found Mu easier to resolve than Delta. Not enough is known about the diagonal supports used to blame the exceptions on their diffraction effects. Most 6-inch reflectors split Delta Cygni at pow-



A resolution chart for Delta Cygni, from amateur observations with reflectors, except for a refractor at "R." Mirror diameters are in inches.

ers over 200x. Generally, 4-inch reflectors failed, but several 4-inch off-axis instruments succeeded with more than 200x, and one 3-inch off-axis made it at 365x.

According to Aitken's formula for unequal pairs, Delta should take a 6- or 7-inch to split it well. The general run of reports confirms this, but there is a tendency for 5-inch apertures to suffice at powers over 300x. But most amazing is the work of the off-axis reflectors, which seem to perform to refractor limits. As for the refractors, Chester Smith in California stopped his down to 2.88 inches before he lost the companion of Delta, but the same instrument, with a 1-inch central stop, failed at a 4-inch aperture and a power of 200.

Observers who care for doubles may try the following pairs. The position angles and distances cited are for 1956. ADS 8197 (11h 29m.5, +61° 22′; 1950), magnitudes 5.7 and 7.1, position angle 65°.3, distance 0″.99; Gamma Virginis, 3.6 and 3.7, 310°.0, 5″.24; and Zeta Bootis, 4.6 and 4.6, 310°.0, 1″.17.

For telescope users in the tropics and the Southern Hemisphere, there is the fine binary, Alpha Centauri, 0.3 and 1.7, 39°.9, 5″.06.

WALTER SCOTT HOUSTON

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

VARIABLE STAR MAXIMA

May 9, W Lyrae, 181136, 8.0; 14, R Pegasi, 230110, 7.9; 19, T Columbae, 051533, 7.6; 19, S Ursae Majoris, 123961, 7.9; 20, Chi Cygni, 194632, 5.3; 23, R Trianguli, 023133, 6.3; 25, R Cygni, 193449, 7.3; 26, U Herculis, 162119, 7.6.

June 1, T Centauri, 133633, 6.1; 2, RR Scorpii, 165030, 6.0; 3, RS Cygni, 200938, 7.4.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

MINIMA OF ALGOL

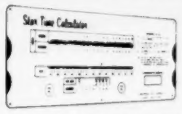
May 3, 18:35; 6, 15:24; 9, 12:13; 12, 9:02; 15, 5:51; 18, 2:40; 20, 23:29; 23, 20:18; 26, 17:06; 29, 13:55. June 1, 10:44; 4, 7:32; 7, 4:21; 10, 1:10.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

VENUS-MOON PHOTOGRAPHS

The request for photographs of the Venus-Moon conjunction on March 15th has been very well answered by the readers of *Sky and Telescope*. In order to process the large number of pictures received, it is necessary to postpone their publication to a later issue.—Ed.

NEW - NEW - NEW



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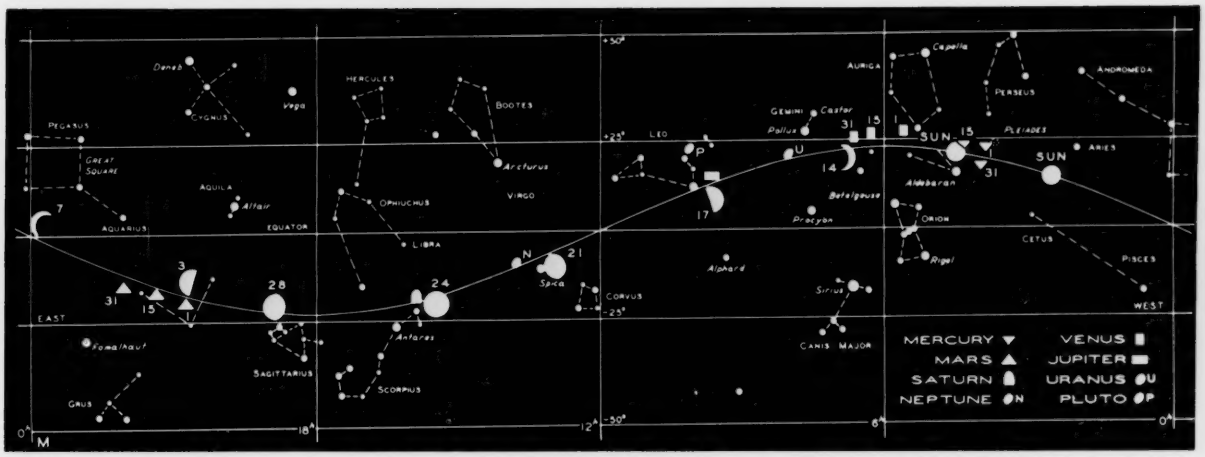

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury will be better placed for view at the end of April and in early May than at any other time this year, for Northern Hemisphere observers. Greatest elongation occurs on May 2nd, with the planet 20° 56′ east of the sun. On that date, Mercury will be a +0.4-magnitude object just east of the Pleiades in Taurus, and will set nearly two hours after the sun. After the first week in May, Mercury will be difficult to view, as it moves rapidly toward the sun.

Venus moves from Taurus into Gemini during May. On the 1st, it sets nearly four hours after the sun, but only two hours after by the month's end. Greatest brightness occurs on May 16th, when the planet appears at magnitude −4.2.

Telescopically, the crescent of Venus narrows rapidly during May, as the percentage of the disk that is illuminated decreases from 39 to 14. Meanwhile, the apparent diameter of the disk increases from 30″ to 47″.

The moon will undergo a partial eclipse on May 24th, visible only in the Eastern Hemisphere. The eclipse begins at 13:18.7 UT and ends at 17:13.8. The eclipse is nearly total, as 97 per cent of the moon's diameter will be inside the earth's shadow at mid-eclipse. The next total lunar eclipse, on November 18, 1956, will be visible in the Americas.

Mars, rising shortly after midnight, travels through Capricornus, entering Aquarius at the end of the month. The red planet continues to brighten, attaining magnitude 0.0 on the 15th. At that time the disk of Mars is 9″.9 in diameter.

Jupiter comes to eastern quadrature with the sun on May 13th, setting about 1 a.m. Located about 7° west of Regulus in Leo, the planet is moving eastward. On the 15th, Jupiter appears at magnitude −1.6, and its telescopic disk is 37″ in equatorial diameter.

Saturn reaches opposition to the sun on May 20th, when its distance from the earth is 832 million miles. At that time, the planet is an object of magnitude +0.2, in retrograde motion about 1° south of the star Theta Librae. As viewed in a telescope, the longest diameter of the ring system will be 42″ on the 20th, and the plane of the rings will be inclined 21°.2 to the line of sight.

Uranus will be observable only during evening hours. This 6th-magnitude planet is moving slowly eastward in Cancer. On the 15th, the right ascension and declination of Uranus are $8^h\ 04^m.4$, +20° 57′ (1950); these co-ordinates are changing by $+1^m.0$ and −3′ per week, respectively.

Neptune is above the horizon most of the night, and may be observed with binoculars. It continues in retrograde motion in eastern Virgo. Neptune's co-ordinates on May 15th are $13^h\ 47^m.7$, −9° 12′ (1950), and their weekly changes are $-0^m.6$ and +3′, respectively. For maps showing the paths of Uranus and Neptune, see page 191 of the February, 1956, issue. E. O.

MAY METEORS

The Eta Aquarid meteor shower can be observed during the first 10 days of May. Maximum activity occurs on the night of May 4-5, when about 12 meteors may be seen per hour under good conditions. The last quarter moon may interfere, but watch during morning hours for swift meteors with long paths. The radiant point of this stream is at right ascension $22^h\ 24^m$, declination 0° on May 4th.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Vesta, 4, 6.0. April 27, 14:21.8 −1-27. May 7, 14:15.3 − 1-03; 17, 14:07.0 −0-59; 27, 14:00.9 −1-16. June 6, 13:57.5 −1-55; 16, 13:57.2 −2-52. For a map of Vesta's path among the stars, see page 145, January issue.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MOON PHASES AND DISTANCE

Last quarter	May 3,	2:55
New moon	May 10,	13:04
First quarter	May 17,	5:15
Full moon	May 24,	15:26
Last quarter	June 1,	19:13

	May	Distance	Diameter
Apogee	1, 5h	251,300 mi.	29′ 33″
Perigee	13, 1h	226,300 mi.	32′ 49″
Apogee	28, 21h	251,900 mi.	29′ 29″
	June		
Perigee	10, 3h	223,500 mi.	33′ 13″

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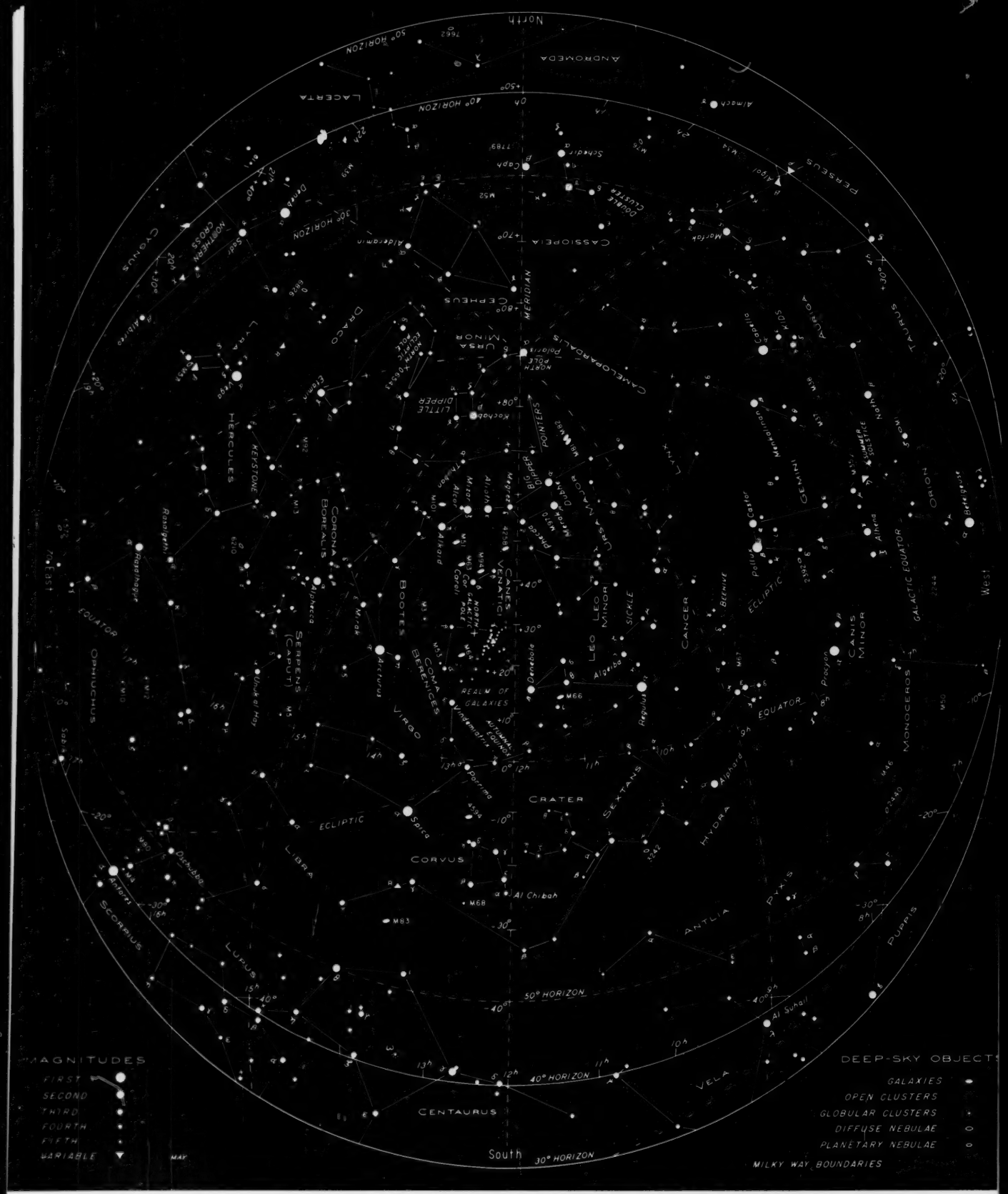

STARS FOR MAY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of May, respectively. For other dates, add or subtract ½ hour per week.

The bright orange star Arcturus now dominates the eastern sky. Among the spring constellations farther east Corona Borealis, the Northern Crown, and Hercules, the Kneeler, invite attention. At this time the Big Dipper is nearly overhead, a good starting area for spring constellation study.

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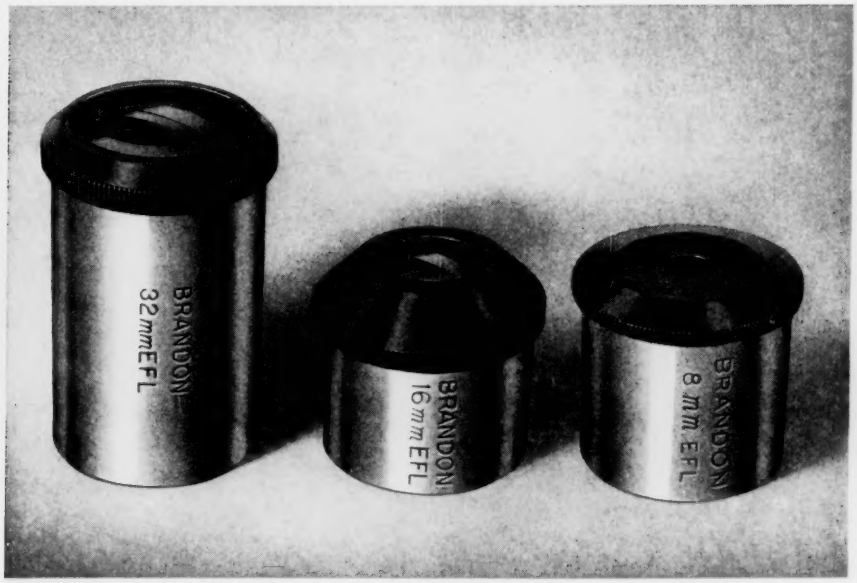

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ARCHAEOLOGICAL FIND REVEALS EARLY UNITRON HISTORY

Discovery of H. A. Rey Recalls Long-Forgotten Events

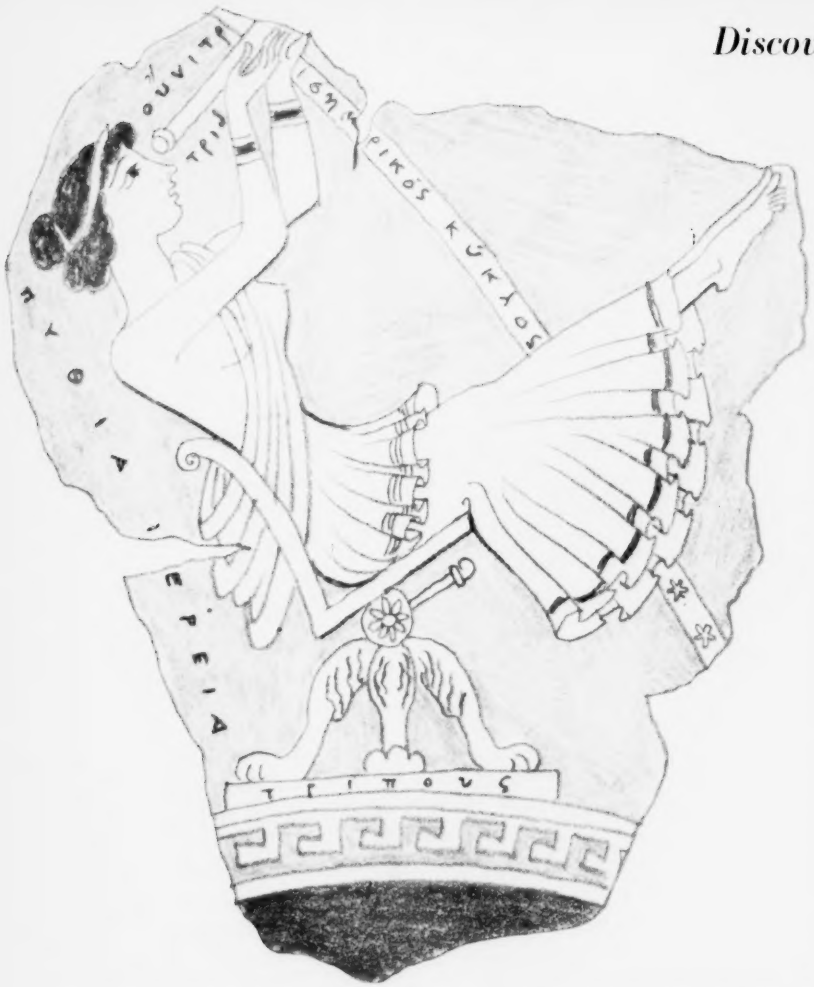

Illustration of a fragment of a Greek amphora circa 480 B.C., showing Delphic priestess viewing through archaic UNITRON 3" Refractor on equatorially-mounted chair. Reproduced courtesy "Archiv für Vasenbildermerkwürdigkeiten."

A chance discovery of H. A. Rey, well-known author[1] and student of antiquity has added a new chapter to our knowledge of the history of UNITRON Refractors[2] and of the telescope in general[3].

Mr. Rey made his discovery known on April 1st in a letter to the Curator of the UNITRON Collection of Curiosa. Because of its importance to the history of science, this letter is reproduced here together with such explanation as has been provided by subsequent research. Footnotes and references have been added to guide those desiring to pursue the matter further. Reference is made only to treatises readily available. The letter follows:

"Your recent report[4] on the prediction made by the Delphic Oracle[5] to Eudoxus of Cnidus[6] was read with great interest. By an odd coincidence I happened to leaf through an old issue of the *Archiv für Vasenbildermerkwürdigkeiten*[7]—a now defunct periodical in the field of Greek archaeology—and came upon an illustration which I was sure would interest you, so I traced it as well as I knew how and am now mailing it to you.

"There is no doubt that the lady on the chair is the Pythia[8] because it says so. But that of course is the item of least importance. What is really important is the chair itself, mounted on a tripod: I have measured the angle between the plane of the chair's seat and the stone slab on which the tripod rests, and the angle turns out about 38°, which is the latitude of Delphi, no more, no less! Now, could that be purely accidental? Nor is that all. The lettered strip going from the upper left to the lower right of the fragment carries the legend: ισημ■ρικος κυκλος[9].

"Now, that missing letter is probably an epsilon, it must be a vowel; the only consonants the Greek language permits between μ and ρ would be β or π, and they give no sense, nor does any vowel except ε—but forgive my digressions into linguistic details—and the word ισημερικος means 'equator.' In other words, the chair on which the priestess is seated is equatorially mounted! To my knowledge, this is the earliest pictorial representation of an E.M.

"Am I finished? By no means. The woman is holding a tube in her hands, and what do the inscriptions above and below the tube say? 'ουνιτρ . . .' and 'τριδ . . . .' Now, the first clearly means 'UNITRON,' and 'τριδ . . .' is the beginning of a word 'τριδεκατυλος' which signifies 'three-inched.' Wouldn't you agree that this is the earliest design of a telescope? And a UNITRON, at that! An archaic model[10], of course, but still a UNITRON.

"It is astonishing that the girl should hold a 3" UNITRON in her bare hands[11], but then we have to consider that those priestesses were not ordinary women, and besides she was probably in a trance, and persons in a trance often develop surprising physical powers[12]."

The foregoing letter from H. A. Rey naturally aroused curiosity and a committee was formed to investigate further.

A visit to the Attic pottery collection of the Museum of Fine Arts in Boston[13] indicated a date of about 480 B.C. for the fragment and an explanation of the picture was sought by consulting the UNITRON files for that period. After much searching in vain among long-forgotten clay tablets[14], attention was turned to a stack of papyrus rolls which these many years had been mistaken for grass-cloth wallpaper. Diligent study of one of these scrolls has established the remarkable fact—overlooked until this time—that UNITRON used to rent advertising space on Attic pottery, and that the Rey fragment is therefore an early UNITRON advertisement!

Surprising as it must seem at first sight, we must remember that in those early days every household used pottery, and hence these vases would be an excellent advertising medium. And this is confirmed by a well-known saying of Herodotus[15], "In Philadelphia, nearly everyone reads the amphora," a modern version[16] of which is still current.

UNITRON advertising on these vases was sharply curtailed after the Peloponnesian War—a consequence, no doubt of the drop in circulation of Attic pottery. The papyrus briefly mentions a transfer of the ads to the shields of soldiers in the army of Alexander the Great. Unfortunately, the papyrus ends at this point and can make no further contribution.

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[1] H. A. Rey, *The Stars: A New Way to See Them*, Houghton Mifflin Co., Boston, Mass.

[2] What is known about present-day UNITRONS is summarized in the new *UNITRON Catalog and Observers Guide* available free of charge from the UNITRON Instrument Division of United Scientific Co., 204-6 Milk St., Boston 9, Mass. See pages 314 and 315 of this journal.

[3] For the state of knowledge prior to this discovery, see H. C. King, *The History of the Telescope*, Sky Publishing Corp., Cambridge, Mass.

[4] *Sky and Telescope*, February, 1956, page 178.

[5] For a full account see K. Latte, in A. Pauly, G. Wissowa, and W. Kroll, *Real-Encyclopadie d. Klassischen Altertumswissenschaft*, xviii, 839ff.

[6] See George de Santillana, "Eudoxus and Plato: A Study in Chronology," *Isis*, 32, pages 248-262.

[7] Band 326, Heft 12.

[8] The Delphic Priestess (of Pythian Apollo).

[9] The use of lower-case letters, not invented until hundreds of years later, can only be explained by the influence of the prophetic priestess.

[10] Slow-motion controls were lacking in archaic UNITRONS.

[11] UNITRON Refractors have always been available separately, without mountings.

[12] See Auguste Bouchi-Leclerc, *Histoire de la divination dans l'antiquité*, 4 vols., 1879-1882.

[13] See L. D. Cashey and J. D. Beazley, *Attic Vase Paintings in The Museum of Fine Arts*, parts I and II, 1931 and 1954.

[14] *Catalog of Unclassified Clay Tablets in the Basement of 204-6 Milk St.* Unpublished.

[15] See *The Histories*, Book V.

[16] See the Philadelphia *Evening Bulletin*.

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